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TECHNICAL RESOURCE DOCUMENT
TREATMENT TECHNOLOGIES FOR HALOGENATED ORGANIC CONTAINING WASTES

Volume I

by

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This halogenated organics technical resource document (TRD) is one of a series of five TRDs that are being prepared by the Hazardous Waste Engineering Research Laboratory. It provides information that can be used by environmental regulatory agencies and others as a source of technical information describing alternatives to the land disposal of nonsolvent halogenated wastes. These alternatives include waste minimization/recovery, treatment, and disposal of waste streams. Although emphasis is placed on the presentation of performance data for proven technologies, information dealing with the applicability of other emerging technologies is presented as well.

The treatment technologies discussed in this TRD include biological treatment as well as the following physical, chemical, and thermal treatment technologies:

Physical Treatment	Chemical Treatment	Thermal Treatment
Distillation	Wet Air Oxidation	Incineration
Evaporation	Supercritical Water	Molten Glass
Steam-Stripping	UV/Ozone Oxidation	Molten Salt
Solvent Extraction	Chemical Dechlorination	Pyrolysis
Carbon Adsorption	In Situ Vitrification	

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ABSTRACT

This halogenated organics technical resource document (TRD) is one of a series of five TRDs that are being prepared by the Hazardous Waste Engineering Research Laboratory. It provides information that can be used by environmental regulatory agencies and others as a source of technical information describing alternatives to the land disposal of nonsolvent halogenated wastes. These alternatives include waste minimization/recovery, treatment, and disposal of waste streams. Although emphasis is placed on the presentation of performance data for proven technologies, information dealing with the applicability of other emerging technologies is presented as well.

Halogenated organic constituents of concern include all listed halogenated organics not classified as solvents, dioxins, or polychlorinated biphenyls. An estimated 24.2 million gallons of these nonsolvent halogenated wastes were generated in 1981. Of this total, about 3.2 million gallons were land disposed.

The treatment technologies discussed in this TRD include biological treatment as well as the following physical, chemical, and thermal treatment technologies:

Physical Treatment	Chemical Treatment	Thermal Treatment
Distillation	Wet Air Oxidation	Incineration
Evaporation	Supercritical Water	Molten Glass
Steam-Stripping	UV/Ozone Oxidation	Molten Salt
Solvent Extraction	Chemical Dechlorination	Pyrolysis
Carbon Adsorption	In Situ Vitrification	

Each treatment system, plus solidification/fixation processes for treatment residuals, is examined with regard to the following factors:

1. Process description, including design and operating parameters, pretreatment requirements, and post-treatment of residuals;

2. Performance data available from bench, pilot, and full-scale studies;

3. Cost of treatment; and

4. Present status of the process.

A final section provides approaches to identifying and selecting appropriate technologies for specific halogenated organic compound bearing waste streams.

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COMPARATIVE ECOLOGICAL RISK

A REPORT OF THE ECOLOGICAL RISK WORKGROUP

FEBRUARY 1987

SECTION 1

INTRODUCTION

Section 3004 of the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments of 1984 (HSWA), prohibits the continued placement of RCRA-regulated hazardous wastes in or on the land, including placement in landfills, land treatment areas, waste piles, and surface impoundments (with certain exceptions for surface impoundments used for the treatment of hazardous wastes). The amendments specify dates by which these prohibitions are to take effect for specific hazardous wastes as shown in Table 1.1. After the effective date of a prohibition, wastes may only be land disposed if: (1) they comply with treatment standards promulgated by the Agency that minimize short-term and long-term threats arising from land disposal; or (2) the Agency has approved a site-specific petition demonstrating, to a reasonable degree of certainty, that there will be no migration from the disposal unit for as long as the waste remains hazardous. In addition, the statute authorizes the Agency to extend the effective dates of prohibitions for up to 2 years nationwide if it is determined that there is insufficient alternative treatment, recovery or disposal capacity.

PURPOSE

This Technical Resource Document (TRD) for halogenated organic wastes identifies recovery and treatment alternatives to land disposal for these wastes and provides performance data and other technical information needed to assess potentially applicable alternatives. This document is one of a series of documents designed to assist regulatory agency and industrial personnel in meeting the land disposal bans promulgated by the 1984 RCRA Amendments.*

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*Technical Resource Documents for dioxin and solvent bearing wastes were issued earlier in 1986. The treatment of halogenated solvents has been discussed in the solvent TRD and these solvent compounds are not specifically addressed in this document.

INTRODUCTION

The Comparative Risk Project was formally initiated in May 1986, following several months of planning and organizational activity. Its objective was to estimate and rank current environmental risk under existing levels of control for the purpose of assisting EPA in setting program and budget priorities. Four subordinate workgroups were chartered to deal with cancer risks, noncancer health risks, welfare effects and ecological effects. Each workgroup was to address, evaluate, and to the extent possible rank the risks presented by 31 environmental problems which EPA has some responsibility and authority to control. This report presents the efforts and conclusions of the Ecological Risk Workgroup.

We believe that our task was quite different from the tasks of the other workgroups. While not necessarily more difficult, it was more complex in several respects. The risks we evaluated are not risks to a single species, man, nor to interests that can be valued in dollars. They are risks of damage to entire ecological systems, to geographical regions, and to the biosphere itself. Ecological systems are complicated entities composed of multiple plant and animal populations and the associated physical environment, and contain a host of internal relationships. The severity of risk to ecosystems due to chemical and physical stresses seldom can be measured just by the weakening or destruction of a species, or even by the elimination or weakening of an individual relationship; severity of risk is measured by changes in the basic characteristics of the system as a whole. In general, we evaluated these effects by estimating interference with the normal structure and functioning of ecological systems, and the period of time they typically require to recover from environmental stress. Furthermore, there are many, very different ecosystem types, and they respond differently to the stresses we evaluated; some are relatively strong and stable in reacting to the same stress agents that produce severe reactions in other ecosystems.

We believe that readers will be helped by some brief background on ecosystems, and thus how damage to those systems may occur. Ecosystems are complex combinations of plants and animals interacting with each other and with their physical environment. These systems manifest structural and functional patterns; they obtain the energy and raw materials necessary for growth, maintenance and reproduction from the physical environment, and from living parts of the system. All living organisms absorb, transform and circulate materials and energy through the ecosystem.

In a broad sense, ecosystems can range in size from a drop of water to the entire biosphere. Ecosystems are biologically and physically different from one another with organisms specially adapted to their particular environments. Regardless of size of an ecosystem, all components of ecosystems operate as parts of the whole ecosystem.

Theoretically, ecosystems and the internal interactions in the ecosystem among plants, animals and the physical environment tend to attain stability over time. Thus the structural and functional properties of ecosystems should remain relatively unchanged over long periods of time. Actually, ecosystems exhibit varying degrees of natural fluctuation around an environmentally determined equilibrium point. Mechanisms for stability operate at many levels within ecosystems to maintain this dynamic balance. It is through these mechanisms that ecosystems derive their capacity to accommodate anthropogenic as well as natural disturbances.

Ecosystems can nevertheless be delicate. Modify the particular mechanisms for stability that keep the system stable, and the ecological balance changes. Interdependency in an ecosystem can mean that the decline of one species can potentially affect the entire system, though frequently one species can be substituted for another in an ecosystem without seriously affecting the ecosystem as a whole. Disruptions to ecosystems have been compared to the ripple effect that occurs when a stone has been thrown into a pond. Much of ecology is an attempt to ascertain the consequence of each of these ripples.

Traditional toxicological approaches to assessing risk to individual species are not very useful in evaluating the likely response of ecosystems to anthropogenic disturbance. (They would not even be relevant in evaluating physical alteration of habitat, as distinct from chemical stress.) The results of tests on individuals or single species frequently cannot be directly translated into effects on populations in natural communities, let alone overall impacts on ecosystems, with their large numbers of living and non-living components and networks of interrelationships. What is needed to assess ecological risks is evidence as to how whole natural systems react to stresses. Such system-level studies are frequently not available. It is within this context that we have done our best to assess risk to ecological systems.

In this report, we have used the term "risk assessment" to denote the process we employed in ranking the problems or to characterize the methods used to estimate ecological effects. We have used this language because it is the common currency of the larger Comparative Risk Project, and it serves as a convenient shorthand descriptor. It is critical, however, for the reader to keep in mind that the phrase has a different operational meaning in our context. Specifically, it should not be confused with common useage in evaluating human health response to toxic substances, where risk assessment has come to be widely perceived as a highly quantitative, sophisticated, analytic process. Risks are often expressed as the probability of occurrence for an event of interest, such as contracting cancer within a lifetime. In the context of our efforts, the term has a meaning much closer to that of the term "environmental impact assessment", which often involves assessments of exposure potentials and effects, and may involve predictions, but only rarely is quantitative and almost never probabilistic.

Nor does the workgroup claim to have conducted this assessment as a traditional scientific analysis with its attendant data quality, reproduceability, documentation, and other requirements. Rather, the assessment was conducted as a consensus building process relying on available data and group debate, and involving much individual judgment. This is not to imply, however, that the process lacked objectivity or rigor -- both of which are attainable in a consensual process. In light of data limitations, one consequence of this approach is that visibility of a particular problem or issue carries a great deal of weight, and visible issues may tend to "float to the top" while less visible matters may remain unaddressed. However, we believe that a more "scientific" analysis would not be likely to change the results of our ranking substantially (given the same set and definition of problems). If the results were to change, it would probably be at the margin or among the lower ranked problems.

As noted, the workgroup experienced difficulty in acquiring data. This resulted partly from the difficulty of bringing data together in the time available, and partly from the fact that adequate data do not exist for many of the problem areas.

We believe, as indicated above, that the evaluations are substantially sound. This was largely due to the recurring, intense effort of many of the members of the workgroup in many meetings. The workgroup was fortunate in having many members with substantive background and training in ecology to back up broad experience and personal knowledge about pollutant releases and ecological responses across the Agency's programs. We also acknowledge with gratitude the great assistance we received from the expert panel described later in this report. Thus, while we expect that better data and more refined method can lead to more confidence, we believe that the conclusions presented here can be usefully applied in determining agency priorities.

Organization of Report

The primary responsibility of the work group was to rank specified environmental problems according to ecological risk; the results are summarized in Part I. Also contained in Part I are certain general conclusions the workgroup reached on ecological risks and how EPA addresses them, together with related recommendations.

Part II of the report describes in more detail the workgroup's approach and methods used to develop the rankings. Part II also desribes the assistance provided us by the expert panel of scientists convened by the Cornell Ecosystems Research Center.

Part III includes comments and observations on ecological risk and its priority in EPA, and describes in more detail the difficulties in ranking ecological risks.

Part IV is an appendix containing the full report of the panel of experts convened by the Cornell Ecosystems Research Center, and the papers on individual problems which we used in developing the rankings.

The members of the workgroup encourage a careful reading of all parts of this report.

PART I

RANKING OF PROBLEMS; CONCLUSIONS AND RECOMMENDATIONS

Over the course of several months, the workgroup conducted several successive rankings of the environmental problems, and contemporaneously developed and refined its methodology for evaluating them -- the latter with the notable contribution of the expert panel convened by the Cornell Ecosystems Research Center. Part I contains a brief description of the methodology and its development; our rankings and the basis for ranking position; and our conclusions and recommendations on several issues and concerns that arose in the course of our conduct of the ranking exercise.

RANKING OF PROBLEMS

Approach and Methodology

Here is how the workgroup approached its task of ranking the relative ecological risk of a set of environmental problems.

° We modified the initial list of environmental problems by dropping five which presented little or no ecological risk (e.g., indoor air pollution); by combining others where we felt it more useful for assessing ecological risk; and by redefining others to account better for ecological risk. We ended up with 22 problems. Our modification of the list is detailed in Part II, and the modified list is Table 3. We note that the original list (as well as our modified list) both include disparate and overlapping environmental problems of different magnitudes; this tends to bias the rankings.

° For purposes of evaluating ecological risk, in our first ranking we developed nineteen categories of ecosystems and other objects of ecological concern. Subsequently, following the workshop held by the expert panel, we decided to use the panel's reasonably similar breakout into sixteen ecosystems of concern (four freshwater, three marine and estuarine, four wetland and five terrestrial). (See Part II)

° The expert panel, in evaluating potential risk to ecosystems, broke out the types of stresses associated with the problems into 26 airborne, waterborne, and other "stress agents" (e.g., waterborne toxic organics, gaseous phytotoxicants, radionuclides). We decided this was a valuable perspective and used these stress agent categories in our approach to ranking problems. (see Part II)

° The panel also characterized these stress agents as to scale of potential impact -- whether the stress agent's impacts would be limited to local ecosystems, or would affect broader geographical regions or the entire biosphere. We too applied this scalar concept in our ranking. We did not attempt to agree on a precise definition of "regional" and "local" (i.e., we did not use a 50-mile radius or other specific measure of scale as defining the boundary between local and regional).

° To evaluate and rank ecological impacts deriving from each of the 22 environmental problem areas (as distinct from potential impact from a particular stress agent, which may result from several problem areas), we needed problem-related information concerning sources and emissions, and especially concerning exposures (including geographical extent, location, intensity, frequency and the like). For this purpose, problem papers were prepared for each of the twenty-two problems (See Part IV). We used the information and judgments in these papers, as well as the collective knowledge of the workgroup. As noted elsewhere, our information was weak in many problem areas.

° To assess the risk to ecosystems, the workgroup considered basic changes in the structure of the ecosystems and in their functions as indicators of serious impact. The workgroup also took into account the reversibility of the impact, and the time it would take the ecosystem to recover when the stresses were removed. For many reasons, we concluded we could not use a prescriptive or quantitative approach in taking these factors into account.

° We gave some effort to whether it would be possible and useful to rank ecosystems according to their inherent vulnerability to damage from environmental stresses. We concluded generally that this was not a good approach. Many (perhaps most) ecosystems react differently to different kinds of stresses. Wetlands, for instance, because of their natural assimilative capacity, appear to be relatively less vulnerable to chemical pollution than lakes or streams; however, they are extremely vulnerable to physical alteration or destruction.

° In sum, then, the workgroup evaluated and tried to rank the ecological risk posed by 22 environmental problems by estimating the impact of the problems on many different kinds of ecosystems as well as on broader geographical regions and on the biosphere. The impacts estimated are those that occur under current conditions of control as a result of exposure to the stress agents produced by the problem sources.

RANKING RESULTS

Table 1 summarizes the ranking of 19 environmental problems in terms of ecological risks. These rankings represent a consensus (if not unanimity in every case) of the workgroup. We assigned the problems to six rank groups, with ecological risk judged to be highest in rank group one, descending to least in rank group six. Problems are not ranked within the rank groups. Three problems were not ranked for lack of reasonable certainty.

Table 2 arrays the ranking results in a matrix according to geographic scale of impact -- local, regional, and biospheric. As shown in this matrix, environmental stresses occurring at larger scales tend to be of greater concern. This is true for both ecological and control reasons. Mitigation or amelioration of large-scale ecological impacts is usually difficult. Even low-level impacts that affect large areas can be difficult to detect and trace back to a cause, thus substantially increasing the time before applying controls.

Table 1
Summary Ranking of Ecological Risks

Rank	Environmental Problem	Rationale for Ranking Position[1]
1	Stratospheric ozone depletion (7) CO$_2$ and global warming (8)	Intensity of impact: High (can severely damage all natural systems, particularly primary productivity). Scale of impact: Biospheric Ecosystem recovery: Recovery period extremely long; impacts may be irreversible. Control: Effective controls require coordinated, international effort that will be very difficult to obtain. Uncertainty: Effects of ozone depletion uncertain; ecological response to global warming is well characterized. Rate and timing of the problem is uncertain.
2	Physical alteration of aquatic habitats (13/14) Mining, gas, oil extraction and processing wastes (20)	Physical risks from problems #13/14 and #20 are similar, except #20 includes terrestrial impacts. Intensity of impact: High (can both degrade and completely destroy ecosystem structure and functions). Mining poses severe impacts on water ecosystems. Scale of impact: Local to regional. Ecosystem recovery: Physical impacts are generally irreversible. Control: Low degree of controllability. Uncertainty: High degree of certainty associated with effects.
3	Criteria air pollutants (1) Point-source discharges (9/10) Nonpoint-source discharges and in-place toxics in sediment (11) Pesticides (25/27)	While problems #1, #9/10, 11, and #25-27 do not share common characteristics, they are rank-grouped together. Intensity of impact: High (tend to directly affect ecosystem functions and indirectly affect ecosystem structure). Scale of impact: Local and regional. Ecosystem recovery: Impacts are generally reversible. Control: Degree of control varies among the problems in this rank group; more controllable than rank group #1. Uncertainty: Some uncertainty, but much is known about these effects.

[1] Problems are presented in numerical order within each category of rank; no ranking inference should be made within these categories. The numbers in parentheses following the problems are those used in the Comparative Risk Project listing.

Table 1 (Cont.)

Summary Ranking of Ecological Risks

Rank	Environmental Problem	Rationale for Ranking Position[1]
4	Toxic air pollutants (2)	Intensity of impact: Medium. Growing evidence to indicate that toxic air pollutants responsible for ecological damage. Scale of impact: Local to regional . Ecosystem recovery: Unknown. Control: Unknown, but likely to be difficult Uncertainty: Substantial.
5	Contaminated sludge (12) Inactive hazardous waste sites (17) Municipal waste sites (18) Industrial non-hazardous waste sites (19) Accidental Releases of Toxics (21) Oil spills (22) Other ground water contamination (24)	These problems overall have localized releases and effects Intensity of impacts: Medium (many sources; impacts generally low, but can be high locally). Ecosystem recovery: Uncertain. Control: Variable. Uncertainty: Moderate
6	Radiation other than radon (6) Active hazardous waste sites (16) Underground Storage tanks (23)	These problems are characterized by few large releases, a high degree of control for #6 and #16. Intensity of Impacts: usually low though could be moderate to severe locally in unusual circumstances. Scale of Impact: local Ecosystem recovery: uncertain Uncertainty: moderate

Table 2
Scale of Ecological Risks

	BIOSPHERE	REGIONAL	LOCAL
HIGH	Stratospheric ozone depletion (7) CO_2 and global warming (8)	Criteria air pollutants (1) Point-source discharges (9/10) Nonpoint-source discharges (11) Physical alteration of aquatic habitats (13/14), Mining (20), Pesticides (25-27)	
MEDIUM		Toxic air pollutants (2/3)	Contaminated sludge (12) Inactive hazardous waste sites (17) Municipal waste sites (18) Industrial waste sites (19) Accidental release of toxics (21) Oil spills (22) Other ground water contamination (24)
LOW			Radiation (6) Active hazardous waste sites (16) Underground storage tanks (23)

See footnote to Table 1

BASIS FOR RANKING POSITION

Summarized below are the primary reasons for the ranking of environmental problems shown on Tables 1 and 2. The background papers on individual environmental problems in Part IV should be consulted for information used by the workgroup in deriving the rankings. The numbers in parentheses refer to the problem numbers originally assigned by the Comparative Risk Project.

Stratospheric Ozone Depletion (7)

This problem affects all ecosystems, many in a profound way. Because the ozone layer shields the earth's surface from damaging ultraviolet radiation, ozone depletion could reduce basic ecological processes such as primary productivity. The effect would likely be extreme in many ecosystems (e.g., destruction of the phytoplankton that exist in the surface layer of the oceans). The severity of the potential ecological impacts that could result from increased UV radiation, the global scale of many of the impacts, and their irreversibility more than offset major scientific uncertainties, and result in ranking in the highest risk group.

CO_2 and Global Warming (8)

As with stratospheric ozone depletion, this problem has a very high impact on ecosystems. Industrial-related air emissions, combustion of fossil fuels, deforestation and other releases of CO_2 may cause global temperatures to increase 1.5° - 4.5° C over the next 50-75 years. Such a rapid change would be unprecedented. World-wide global warming would raise the sea level, significantly alter the hydrological cycle and have a major impact on coastal estuaries and tidal wetlands. Global warming is also likely to alter significantly the composition of biomass, especially biomass produced in terrestrial systems. The global extent and irreversible nature of climate alteration, as well as the ecological consequences and difficulty of control, result in ranking in the highest risk group.

Physical Alteration of Aquatic habitats (13/14)

Physical impacts on aquatic systems result from a diversity of human activities such as dredging and filling, channelization, drainage, impoundments, mining, shoreline stabilization, and silvicultural and agricultural activities. These physical insults affect marine, estuarine and freshwater systems by causing direct loss or alteration of habitat, adding suspended matter to the water column, modifying hydrology, and changing ambient water parameters. The threat to wetlands as well as other aquatic systems is very high, and is both local and regional in nature. (Note that physical alterations to terrestrial ecosystems are not included in this problem assessment.)

Mining (20)

The ecological impacts of resource extraction are felt in all major ecological groupings. In addition to physical alteration, the dominant stress agents are: acid mine drainage, toxic inorganics, nutrients, turbidity, oils, solids and groundwater contamination. Acid mine drainage and toxic inorganics, which substantially impact freshwater and terrestrial systems, are of only moderate importance in wetlands and estuaries. Nutrients have high impacts in freshwater systems, moderate to low impact in other systems. Habitat alteration is serious in several types of ecosystems. The risk from mining may be local to regional in scale, and the overall problem is ranked high.

Criteria Air Pollutants (1)

The most prominent stress elements of this problem are acid deposition and ozone (in the troposphere, not the stratosphere). The impacts of ozone on forests and natural ecosystems are long lasting. Acid deposition affects ecosystems where the buffering capacity of soil and water is low, especially in areas of the upper Midwest, the Northeast, Southeast and some areas in the Western mountains. Because of the very high level of emissions, the regional extent of potential impacts, the degree of effectiveness of current controls and the significance of observed effects, this problem ranked high.

Point-Source Discharges (9/10)

Over 65,000 facilities discharge pollutants directly into the Nation's surface waters. Of these, about 39,000 are important sources of both conventional (e.g., solids and biochemical oxygen demand) and toxic pollutants. Most point sources are located in the more heavily populated and industrialized regions of the U.S. Virtually all of the water-borne stress agents identified by the expert panel emanate in point source discharges. They discharge more toxics than sources in any other problem and are major contributors to loadings of BOD, solids, nutrients and chlorine. These releases have resulted in a deterioration of water quality which seriously affects aquatic ecosystems. Over 40% of the assessed stream miles in the U.S. with documented impairments are impacted by point sources, as are half of the impacted estuaries and coastal waters. This problem ranks high because of extent, seriousness and scale of impact.

Nonpoint-Source Discharges (and Sediment bound Toxics) (11)

Nonpoint-source pollution results from activities on the terrestrial environment. Rainfall runoff carries pollution into surface waters. Major sources are agriculture (sediment and chemicals), silviculture (sediment), construction (sediment), urban environments (sediment and chemicals), resource extraction (sediment) and hydrologic modification. The problem is widespread. Over 50% of the nation's lakes that have been assessed and almost 40% of the assessed river miles are impacted by nonpoint-source pollution. This problem ranks high by reason of the extent, scale and significance of its damage to aquatic ecosystems and current inadequate control.

Pesticides (25-27)

About 3.5 billion pounds of formulated pesticide products are used each year --79% by agriculture, 15% by industry and 6% by households. Pesticides are designed to kill living organisms, and unintended exposure to them can be very destructive. Most agricultural production is treated with pesticides. Crops treated with pesticides are grown in the vicinity of most kinds of ecosystems. Aquatic ecosystems receive pesticides directly and through agricultural runoff. Freshwater systems ultimately lead to coastal and estuarine systems, which also receive pesticides directly. Fish and wildlife are exposed to pesticides through inhalation, ingestion, and dermal absorption. Residues on food -- plants, seeds, insects and water--in their habitat result in direct exposure. Certain pesticides bioaccumulate and contaminate food chains. Extent of the problem, severe impact on ecosystems and level of current control contribute to a high ranking.

Toxic Air Pollutants (2)

Sources of toxic air pollutants are widely varied and include traditional air pollutant sources such as emissions from chemical plants, motor vehicles and metallurgical processes, as well as non-traditional sources such as sewage treatment plants. Sources of ecosystem exposure to toxic air pollutants range from industrial emissions to the more routine release of chemicals into the atmosphere as part of the normal operation of countless human activities. Atmospheric loading of toxic pollutants to the Great lakes appears to be a major pathway, but the details are not well understood. Since most of the data available on toxic air pollutants were collected regarding human health concerns, the effect of toxic air pollutants on ecosystems is not well characterized.

Contaminated Sludge (12)

The disposal of contaminated sludge is unlikely to result in extensive damage to natural ecosystems where current and expected control programs are properly implemented. However, since contaminated sludges are clearly a potentially significant source of BOD, solids, nutrients, toxic inorganics and organics, and pathogens, if the EPA permitting and enforcement efforts that are currently in place and expected in the future are not carried out, significant local ecological risks are likely to occur.

Inactive Hazardous Waste Sites (17)

A variety of contaminants at abandoned or inactive waste sites can have localized effects on ecosystems. Information from one survey shows ecosystem injury at 270 sites. Another estimate is that about 6% of sites are likely to cause significant natural resource impacts, including damage to surface waters, wetlands, fisheries, and other impacts. It is difficult, however, to characterize potential ecological effects at superfund sites because of lack of data.

Municipal Nonhazardous Waste Sites (18) and Industrial Nonhazardous Waste Sites (19)

These two problems are summarized together, although the types of sources are somewhat different. Chemicals from these waste sites may contribute directly and indirectly to the degradation of surrounding ecosystems primarily via surface water runoff and air volatilization routes. They can enter surface waters indirectly via ground water. While these waste sites exert only local impacts on ecosystems, their sheer numbers (over 16,000 municipal landfills and almost 200,000 industrial disposal sites) produced the medium ranking.

Accidental Release of Toxic Chemicals and Oil Spills (21 and 22)

These two similar problems are both rated medium. Oil spills are frequent and can have spectacular consequences if the discharge is of sufficient magnitude, but typically spills are small and occur in areas where there is sufficient dilution to result in only a short-term impact. Toxic chemical releases, such as railroad tank cars overturning and spilling into streams, are perhaps more frequent, but the quantities of these spills are typically less than from oil spills. Chemical spills especially in small streams can cause significant effects on stream ecosystems, but these are usually of short duration.

Other Sources of Ground Water Contamination (24)

The overall potential for ecological risk is substantial because of the large number of sources and the lack of controls for many of them. This threat is diminished because ecological impacts occur only when groundwater contaminated by the various sources is discharged from aquifers in sufficient volume and concentration to affect the receiving aquatic or wetland ecosystems. Additionally, the filtering properties of soils and the dilution and dispersion processes of streams and other aquatic systems reduces ecological risk. The large number of sources, plus the lack of control for many sources, resulted in a medium ranking.

Radiation Other Than Radon (6)
Active Hazardous Waste Sites (16)
Underground Storage Tanks (23)

These problems were ranked low for a number of reasons. Active hazardous waste sites are probably adequately controlling releases so as to protect natural ecosystems. Anthropogenic radiation is localized or adequately controlled, effects on ecosystems are rare, and the likelihood of a catastrophic event that would cause serious ecological damage is considered to be low. Underground storage tanks contain hazardous chemicals as well as petroleum products, and there are thousands around, but the release of contamination through groundwater, largely in urbanized environments, means relatively low and localized impacts on ecosystems.

New Toxic Chemicals (28)
Biotechnology (29)
Discarded Plastics (30)

Because of uncertainty, the workgroup did not rank new toxic chemicals, biotechnology, and discarded plastics in the marine environment.

Biotechnology is a new technology. Products of recombinent DNA that EPA has evaluated thus far present very little risk to ecosystems. However, biotechnology could significantly harm ecological systems if bioengineered organisms that would have a competitive advantage in the environment were inadequately controlled and released to the environment.

The ecological risk of new toxic chemicals also cannot be ranked because the extent of current control is not known. If EPA's process for premanufacture review of new chemicals is working, they should have only a small ecological impact, since the chemicals would be regulated before manufacturing. The potential for environmental releases and damage cannot, however, be determined with any great certainty from the information contained in premanufacture submissions. Once EPA lists a chemical, manufacturers can produce it in any quantities, and for different uses, unless EPA promulgates a "significant new use" rule. In general, new toxic chemicals can have the same potential for widespread release as similiar existing industrial chemicals.

The problem of discarded plastics - and in particular, plastics in the marine nevironment - is believed to be significant in terms of wildlife killed (e.g., fish and dolphins), but our information on the extent of effects on populations and on marine ecosystems is insufficient to rank this problem.

CONCLUSIONS AND RECOMMENDATIONS

During the course of its evaluation of ecological risk and ranking of problems, the workgroup developed a number of perceptions about the nature and significance of certain ecological problems, the extent of the Agency's emphasis on those problems, and its capacity to deal with them. (See Part III for extensive discussion of these matters.) In the following section the workgroup offers some conclusions and recommendations that go beyond the direct charge to rank environmental problems.

Two predominant conclusions emerged:

Physical habitat alteration is the stress that has the greatest adverse impact on ecosystems; and

EPA's capability to address ecological impacts is inadequate to support effective action to protect the natural environment.

Habitat Alteration

Physical alteration of aquatic habitats was ranked in the second highest risk group, and alteration or destruction of habitat was a major basis for ranking global warming and mining high. Many activities for which EPA does not have responsibility produce extensive habitat alterations and loss. The workgroup believes that physical alteration or destruction of natural communities -- both aquatic and terrestrial -- is the most significant threat to overall environmental quality that we face now and in the future. While much of the popular coverage of this problem has focussed on other parts of the world (for example, tropical deforestation), the problem is no less significant for the United States. Both the causes and the costs of significant habitat alteration are many and pervasive. Among the more important and visible effects are biotic impoverishment, loss of resource and economic values, loss of recreational potential, and the loss or alteration of major components of biogeochemical cycles and processes, ranging from loss of assimilative capacity of aquatic systems in ameliorating pollution to major changes in the global carbon cycle and attendant changes in atmospheric processes. Although EPA's authorities and tools are limited in this area, we can do more than we are now doing.

Accordingly, *we recommend that the Agency conduct a comprehensive assessment of our authorities, activities, and capabilities in the area of habitat protection*. Where we already have significant authorities and activities, we should determine whether to enhance our efforts by the addition of resources, program or procedural changes, increased research, greater work with other resource management agencies or other means. Examples of areas of current activity include water quality standards (particularly the anti-degradation provisions), construction of sewage treatment plants, regulation of mining and other mineral or fossil fuel extraction, siting of solid/hazardous waste site management facilities, EPA compliance with the National Environmental Policy Act and related statutes/directives (e.g., Floodplain Management Executive Order and Endangered Species Act), and EPA's responsibilities for reviewing the actions of other agencies under section 309 of the Clean Air Act. Where our authorities are less, we should raise attention to habitat protection in our ongoing program planning and decision-making, and consider steps to foster habitat protection. *We also recommend that EPA undertake a comprehensive study, in cooperation with other agencies with responsibilities for protecting ecological values, to describe their authorities and programs for protecting ecological systems and the natural environment from environmental stresses, with special attention to the protection of habitat from alteration or destruction*. This study should look at both U.S. and global sources of ecological stresses and locations of ecological systems impacted. It should direct attention to those programs where EPA could assist other agencies in carrying out their responsibilities. The product of this study could help EPA to decide whether to expand or redirect its own programs to address particular problems, or to work in support of other agencies' programs dealing with them.

EPA's Ecological Capabilities

Many difficult methodological problems were encountered by the workgroup in evaluating ecological risk over the course of this project. EPA does not, in fact, have any generally accepted methodology for assessing ecological risk. The workgroup believes that the unavailability of methods to assess ecological risk and the overall weakness of the data base for evaluation are a reflection of inadequate attention to ecological problems throughout the Agency as well as of the inherent difficulty of evaluating ecological risks.

We recommend that the Agency, as soon as possible, develop and issue interim guidelines for evaluating ecological risk for use by program and regional offices. The experience of the workgroup, together with currently available material developed by ORD, the program offices, and organizations outside EPA, provide a good foundation for describing one or more practical methods for use in evaluating ecological risk. Such methods can serve until such time (probably several years off) that elegant, "final" methodologies can be prepared, reviewed and published. This recommendation does not aim at production of quantitative "risk assessment guidelines", as that term is perceived in EPA in connection with human health risk assessment, but at methods of reasonable intellectual rigor that will predict or estimate impacts qualitatively. We believe that interim guidelines for evaluating ecological risk could be prepared and issued in twelve months. The interim guidelines should be accompanied by a reference compendium of existing methods, models, guidance, etc. for immediate, supplementary use.

We recommend that a strong effort be made to expand and strengthen collection of data relating to the assessment of ecological risk. Monitoring activities should focus on acquiring more and better data on the intensity, geographical distribution and location, and time periods of exposures to ecological stress agents, and data indicating the response (bioeffects) of ecological communities to those stresses. These individual program efforts should be coordinated not only within EPA, but across other Federal Agencies.

We recommend that a number of activities to support individuals and programs engaged in ecological risk assessment be initiated or strengthened:

(1) EPA should assemble and distribute standardized descriptive information on environmental communities and ecosystems in the U.S., including their vulnerability to various environmental stresses. (Example: Aquatic ecoregion atlases under preparation at the Corvallis Laboratory). This should be accompanied by a desk handbook of general information on ecosystems, reference to more detailed sources, etc.

(2) The EPA headquarters Library collection on ecology and natural history is deficient (particularly in comparison with human health and engineering materials), and should be upgraded (for instance, to include free government publications such as the community/estuarine profile series of the United States Fish and Wildlife Service).

(3) Opportunities for basic training in ecology for EPA employees trained in other professional or scientific disciplines should be developed and made available, perhaps through brief courses under the EPA Institute.

(4) Ways to facilitate better communication among EPA staff with responsibilities for ecological risk assessment and senior management should be improved so that professional information and current experience can be exchanged and made available to a wider audience. One method would be a seminar series; a second would be a low budget newsletter.

We recommend that EPA review and amplify its current research and development program for assessing ecological risk. A deeper understanding of ecological systems and how stresses impact them, as well as better techniques for evaluating ecological risk, are needed. Our needs include:

Indicators of ecological stress;

Models for predicting or evaluating ecological response to stress;

Methods for assessing the relative importance of various stresses and impacts; and

Methods for monitoring the health and response of ecological systems and communities.

In carrying out this effort, EPA should both employ its existing research laboratories, and expand support for organizations such as the Cornell Ecosystems Research Center.

We recommend that the Risk Assessment Council initiate, and devote an increasing amount of its effort to, the planning, sponsorship and review of activities relating to the evaluation of ecological risk. The Risk Assessment Council should assume the same responsibility for assuring the availability of guidelines for evaluating ecological risk as it does for guidelines for evaluating human health risk. The membership and staff of the Risk Assessment Council should be adjusted as necessary to reflect this balance.

We recommend that across its full range of programs EPA give substantially greater attention to ecological risks and their control in its planning, priority setting and decision-making *activities.* EPA is not currently using its authorities for ecological protection to their fullest or best advantage. Efforts by EPA to protect threatened ecosystems or restore damaged ecosystems are often capable of producing observable, even reasonable, results.

(1) Wherever there exists the appearance of significant incongruity between evaluations of ecological risk and agency programs that can address those risks, *an examination of programs should be made to determine the reasons for the incongruity and to adjust priority and program content appropriately.*

(2) Revision and initiation of ecological protection activities should *focus particularly on those situations where "marginal utility" appears to be the greatest*. In particular, EPA should target its resources and controls toward those problems in which environmental values are particularly significant and where the risks that can be avoided represent serious damage or destruction.

We further recommend that EPA periodically conduct thorough, comprehensive evaluations of ecological risk, employing the latest evaluation methodology and techniques. A recurring comprehensive focus on ecological problems will expand our understanding of their scope and significance. ORD should perform a stronger role, in cooperation with the program offices.

Recommendations affecting specific problems

Stratospheric Ozone Depletion (7)
Global Warming (8)

The ecological risks of stratospheric ozone depletion and global warming due to increasing releases of CO_2 and other compounds were ranked highest because of their global scale, severe damage to all ecosystems, and irreversibility -- problems of a different kind and vast scale, as compared to other problems we considered. Moreover, they are the least amenable to remedy, given their complexity and pervasiveness, and the difficulty of implementing controls.

In light of the extremely critical nature of these problems, it is imperative that EPA act quickly and decisively. Accordingly, we recommend that, building on its current activity,

(1) EPA review, summarize and evaluate information currently available and investigations underway within and outside EPA concerning the impact of ultraviolet radiation (UV-B) on natural ecosystems (giving special attention to UV-B impacts on the productivity of marine and freshwater systems); determine what further investigations EPA should sponsor to elucidate these impacts; and incorporate statements concerning them in EPA's public communications on the risk deriving from stratospheric ozone depletion; and

(2) The reports and research plans now being formulated for global warming give appropriate coverage and priority to ecological effects; that a comprehensive action strategy provide for protection of ecological values; and guidance be developed for the incorporation of global warming effects in environmental impact assessment.

Pesticides (25/27)

The use of pesticides presents one of the greatest toxic chemical threats to terrestrial ecosystems. The workgroup supports continuing development of ecological risk assessment tools; use of FIFRA to obtain data regarding the ecological risk of pesticides; and reduction of risks to ecosystems by eliminating or restricting those pesticides which pose an unacceptable risk to ecosystems.

Discarded Plastics (30)

A considerable amount is known about kills of fish and other organisms caused by non-degradable plastics (e.g., plastic netting and plastic used to connect six-packs of beverages). Substitute materials appear readily available. EPA should consider development of a regulation under TSCA (and other available authority) to control or prohibit use of non-degradable plastics in products that are used or become waste in the marine environment.

Criteria Air Pollutants (1)

Regional concentrations of criteria pollutants such as sulfur oxides and ozone adversely affect ecological systems. For example, ozone causes a continuum of effects at various levels of organization within plants from the cell to the ecosystem. These effects on plant health and productivity ultimately have consequences for an entire ecosystem. Ecosystem effects may be reflected in species (plant and wildlife) diversification impacts, increased soil erosion, or decreased capacity for watersheds. This potential change in the stability of ecosystems deserves more emphasis in research that could support secondary standards.

Part II

APPROACH AND METHODS

This part describes the approach used by the work group in developing ecological risk rankings for a revised list of environmental problems. The work group set out to develop a pragmatic method to use for comparing the magnitude of ecological risks. Members of the work group were chosen either for their ecological background and training or for their overall knowledge of the environmental problems within EPA's program areas. Through an iterative process involving many meetings, preparation of background papers, and assistance from a group of academic scientists, the work group evaluated the environmental problems from an ecological perspective and formed a consensus on the significance of ecological impacts for each problem area.

DEVELOPMENT OF A RANKING METHODOLOGY

Most approaches to risk assessment stress method and procedure, in part because methods and procedures are viewed as insurance against the limitations of human judgement. A quantitative method-oriented approach works well within the context of a well-defined model of a problem. Results derived from the model are interpreted as conclusions about the problem itself.

This approach does not work so well for ill-defined and poorly understood problems for which generally accepted models and adequate data do not exist. The task of performing a comparative ecological risk assessment across 31 broadly defined "environmental problems" and a number of structurally and functionally different ecosystems exemplifies a situation where approaches relying less on detailed, quantitative method must play a central role.

In these circumstances, the ecological risk workgroup conducted an initial assessment. This was followed by analyses and refinement of our methodological approach and preparation of material to define the environmental problems. This resulted in the approach and information used by the workgroup in its ultimate ranking of problems.

Initial Assessment

Our initial task was to define a set of ecosystems on which to focus the evaluation. While evaluating only a few ecosystem categories would most likely result in missing important consequences and distinctions, broadening the ecosystem categories too far would make the assessment unwieldy, and complicated by lack of data. The work group decided initially upon the following categories of ecosystems:

1. Marine and estuarine systems
    a. deep ocean
    b. shallow coastal waters
    c. estuaries
    d. tidal wetlands

2. Freshwater systems
    a. cold water streams
    b. warm water streams
    c. lakes
    d. wetlands

3. Terrestrial systems
    a. arctic and alpine tundra
    b. boreal coniferous forests
    c. eastern deciduous forests
    d. grasslands
    e. hot deserts
    f. subalpine coniferous forest (excludes boreal)
    g. broad-leaved evergreen and subtropical forests
    h. other
        - western riparian zones
        - barrier islands
        - coastal dune-scrub

4. Special ecological areas/factors
    a. soil - structure and microbiota
    b. highly vulnerable animals, such as top predators, marine mammals, relict populations (e.g., fishes of desert springs)
    c. migratory birds

A second task was to review the list of 31 environmental problems to screen out, redefine or combine them where it would be likely to sharpen the results of our evaluation. The following changes were made:

- Problems #4 (Radon - indoor air pollution only), #5 (Indoor air pollution other than radon), #15 (Drinking water at the tap), #26 (Pesticide risk to applicators), and #31 (Worker exposure to chemicals) were eliminated from consideration because by definition they were limited to health effects or the indoor environment.

- Problems #13 (To estuaries near coastal waters and oceans from all sources) and #14 (To wetlands from all sources) are ecosystem categories, rather than sources of pollutants. Both are included in the ecosystems to be considered by the workgroup. Problem #13/14 was redefined as dredging, filling, channelization, and other physical modification of aquatic systems. (Note: As a result of this redefinition and neglect to provide elsewhere, we did not rank the ecological effects associated with ocean dumping or ocean incineration.)

- Problem #20 (Mining wastes) was expanded so as to include not only the disposal of mining wastes, but also any ecological impacts stemming from extraction of mineral resources and their beneficiation (including oil and gas).

- Problem #11 (Nonpoint-source discharges to surface water) was expanded to include in-place toxicants in the sediment.

- Problem #30 (Consumer product exposure) was in our evaluation limited to ecological effects of discarded plastic materials in the marine environment.

- Problems #2 and #3 were combined, as were #9 and #10, and #25 and #27.

As a result of these revisions, the number of environmental problems we considered was reduced from 31 to 22. A complete list of the modified problems addressed by the workgroup is shown in Table 3.

Using these problems and the ecosystem categorization above, the work group conducted a preliminary subjective assessment of each problem on an ecosystem-by-ecosystem basis, ranking the problems as high, medium or low. The general criteria used for this ranking follow.

1. direct physical destruction or major alteration;
2. changes in community structure/function;
3. changes in species richness and diversity;
4. threats to/loss of rare or endangered species;
5. localized versus national scale of impacts.

Table 3

Modified List of Environmental Problems

1. Criteria air pollutants from mobile and stationary sources -- includes acid precipitation
2/3. Hazardous/toxic air pollutants and other pollutants such as fluorides and total reduced sulfur
6. Radiation - Other than radon
7. Substances suspected of depleting stratospheric ozone layer (e.g., chlorofluorocarbons)
8. CO_2 and global warming
9/10. Direct and indirect point-source discharges to surface waters (e.g., from POTWs, industrial dischargers)
11. Nonpoint-source discharges to surface water, plus in place toxics in sediment
12. Contaminated sludge - includes municipal and scrubber sludges
13/14. Physical alteration of aquatic habitat
16. Active hazardous waste sites - includes hazardous waste tanks
17. Inactive hazardous waste sites - Superfund
18. Municipal nonhazardous waste sites
19. Industrial nonhazardous waste sites
20. Mining wastes and extraction
21. Accidental releases of toxics - to all media
22. Accidental oil spills
23. Releases from underground storage tanks - includes product and petroleum tanks, above ground and underground
24. Other groundwater contamination - includes septic tanks, road salt, injection wells, etc.
25/27. Pesticide residues on food eaten by humans or wildlife; and other pesticide risks - includes leaching and runoff, deposition from spraying
28. New toxic chemicals
29. Biotechnology
30. Consumer products - limited to plastic material

The general purpose of this initial assessment was to test the feasibility and practicality of the overall approach, to determine if the ecosystem categories and criteria were meaningful, and to gain insight into the ranking process in order to determine how best to focus the group's efforts. The results shown in Table 4 reflect judgments based on information generated in the assessment process, as well as information from individual experience. Readers will note that considerable change took place between this initial assessment and the final ranking shown in Table 1.

Following the preliminary assessment, the work group undertook to develop background papers describing the environmental problems, as well as impacts of the problems on ecosystems. We arranged for an outside panel of ecological experts to comment on the workgroup's approach and independently assess the environmental problems. We worked on developing a more systematic ranking scheme. We also explored the possibility of determining the relative ability of different ecosystems to resist structural and functional displacement and to recover from damage. We concluded that it was not feasible to evaluate an ecosystem's vulnerability independent of pollutant stresses.

Table 4
Preliminary Assessment by EPA Work Group of Problems by Ecosystems

Key:
- = no effect
U = unknown
L = low
M = medium
H = high
(blank = not rated)

	Deep Ocean	Coastal	Estuaries	Tidal Wetlands	Cold Streams	Warm Streams	Lakes	Wetlands	Tundra	Boreal Forest	Deciduous Forest	Grassland	Desert	Subalpine Forest	Tropical Forest	Special Zones	Soil	Vulnerable Species	Migratory Birds	Whole Problem "Rough Cut"
1 Criteria air pollutants	-	-	L	L	L	L	H	L	U	H	M	L	L	M	L	-	H	L	-	H
2/3 Hazardous/toxic air pollulants	-	L	M	M	L	L	H	L	L	L	L	L	L	L	L	L	L	M	M	H
6 Radiation - other than radon	-	-	U	U	U	U	U	U	U	U	L	U	L	L	U	-	L	-	-	L
7 Ozone depletion	M	L	-	-	-	-	L	-	-	-	-	-	-	-	-	U	-	-	-	L
8 CO_2/global warming	-	M	H	H	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M
9/10 Point sources to surface water	-	M	H	H	H	H	H	H	-	-	-	-	-	-	-	U	-	H	L	H
11 Nonpoint sources to surface water	-	M	H	H	H	H	H	H	-	-	-	-	-	-	-	U	-	H	L	H
12 Contaminated Sludge	L	M	L	L	L	L	L	M	-	L	L	M	-	L	L	U				H
13/14 Physical alteration-aquatic	-	M	H	H	H	H	M	H	-	-	-	-	-	-	-	U				H
16 Active hazardous waste sites	-	L	L	L	L	L	L	L	-	-	-	-	-	-	-	U	L	L	-	L
17 Inactive hazardous waste sites	-	L	M	M	M	M	H	M	-	L	L	L	L	L	L	L	L	L	-	H
18 Municipal nonhazardous waste sites	-	L	L	M	L	L	L	M	L	L	L	L	L	L	L	L	L	L	-	M
19 Industrial nonhazardous waste sites	U	L	L	M	L	L	L	M	H	L	L	L	L	L	L	L	L	L	-	M
20 Mining	L	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H
21 Accidental release of toxics	-	L	L	L	H	H	L	H	U	-	-	-	-	-	-	L	L	L	-	H
22 Oil spills	L	M	H	H	L	L	L	L	U	-	-	-	-	-	-	U	-	M	M	M
23 Releases from storage tanks	-	-	-	L	L	L	L	L	-	-	-	-	-	-	-	-	L	-	-	L
24 Other ground water contamination	-	-	L	L	L	L	M	M	U	U	U	U	U	U	U	L	L	L	-	M
25-27 Pesticides	-	-	H	H	H	H	H	H	U	H	H	H	H	H	H	H	H	H	H	H
28 New toxic chemicals	-	-	L	L	M	M	U	-	-	U	U	U	U	U	U	U	-	U	U	M
29 Biotechnology	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	M

Assistance from a Panel of Scientific Experts

At our request, the Ecosystems Research Center at Cornell University, an EPA Center of Excellence sponsored by the Office of Research and Development, convened a panel of ecological experts to conduct a two-day workshop and provide us with an independent ranking of ecological risks. The panel, which met at EPA headquarters on October 28-29, 1986, consisted of 10 ecologists selected to represent the variety of major ecosystem types in the United States. The list of panel members appears in Table 5.

The primary objective of the panel was independently to evaluate the potential of the environmental problems for causing ecological damage. The panel initially addressed the list of environmental problems as modified by the Ecological Risk Workgroup. The panel discussed the limitations of both problem categorization and the background information supplied by the workgroup. The panel felt that the listed problems were not of comparable categories, and that the problems, as defined, were not primarily related to types of environmental stresses. Individual categories often contained many different types of environmental stresses.

To compare the ecological effects from the problem areas, the panel concluded it would be necessary to both (1) evaluate the potential ecological impacts from different environmental stresses and (2) evaluate the contribution of various anthropogenic stresses with respect to their magnitude, frequency, duration, form, and spatial distribution. Although the panel felt they collectively had the expertise to perform the first type of evaluation, they felt that they could not perform the second type of evaluation. The draft background papers supplied by the workgroup were not considered to be adequate to allow a comprehensive understanding of the contributions of stress agents from the various environmental problem sources.

Thus, the panel decided to identify anthropogenic stresses to ecological systems and to advise us on the potential for ecological effects from each type of stress. The panel began by identifying a comprehensive set of anthropogenic stress agents, including those associated with the listed environmental problems. The stress agents represented a full

Table 5

Cornell Ecosystems Research Center Panel of Experts

Dr. Mark A. Harwell, Ecosystems Research Center, Cornell University, Ithaca, New York. (Chairperson)

Dr. Jim Detling, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado.

Dr. Katherine Ewel, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.

Dr. Robert Friedman, Office of Technology Assessment, U.S. Congress, Washington, D.C.

Dr. W. Frank Harris, Division of Biotic Systems and Resources, U.S. National Science Foundation, Washington, D.C.

Dr. Robert Howarth, Section of Ecology and Systematics, Ecosystems Research Center, Cornell University, Ithaca, New York.

Dr. John R. Kelly, Ecosystems Research Center, Cornell University, Ithaca, New York.

Dr. Michael Pilson, Marine Ecosystem Research Laboratory, University of Rhode Island, Kingston, Rhode Island.

Dr. John Schalles, Department of Biology, Creighton University, Omaha, Nebraska.

Dr. Richard Wiegert, Department of Zoology, University of Georgia, Athens, Georgia.

Ms. Roxanne Marino, Section of Ecology and Systematics, Ecosystems Research Center, Cornell University, Ithaca, New York. (Workshop coordinator) range of ecological stresses, including some not presented by the problems we addressed. These stress agents appear in Table 6, as well as in the panel's full report which appears as an appendix in Part IV.

The panel selected a set of types of ecosystems to consider for potential effects associated with each stress. The criteria for ecosystem selection were (1) to have as few categories as possible, while maintaining sufficient resolution so that differential ecological response could be assigned, and (2) to develop categories that nonspecialists would readily recognize. The list of ecosystems is presented in the panel's report and in modified form in Table 6. (This categorization of ecosystems is quite similar to, but different in many respects from, the categorization we used in our initial assessment.) The panel also separated the scale of ecological effect associated with the stress agents into three levels, biosphere, regional and local ecosystems.

The panel then evaluated the potential of each anthropogenic stress for damaging each ecosystem, and the intensity of the potential damages. As stated above, they did not assess how extensively each stress is currently harming each ecosystem. With this approach the Panel was not limited by the insufficient information provided concerning sources and exposures. Estimating actual rather than potential effects would depend on the nature, intensity, duration, and frequency of the stresses actually applied to each ecosystem. The approach also allowed the panel's results to remain applicable, even as changes occur in the future in the anthropogenic sources and consequent exposures. Table 6 is an abbreviated and reformatted version of the expert panel's consensus as to the potential ecological effects of stress agents on ecosystems. For the panel's own detailed statement of its conclusions as presented to us, together with explanatory notes, see pages 19-30 of the panel's report.

While the panel did not address the relative risk of a particular environmental problem, they did identify the most important environmental stresses at the biosphere, regional and local scales, together with an indication of the problem areas associated with these stresses. Table 7 of this report, taken directly from the panel report, presents this information. For example, they considered toxic organic chemicals transported through surface water systems as of high ecological importance at the local ecosystem level, and noted that this stress could result from industrial effluents, nonpoint-source runoff, waste disposal sites, and other problem sources.

Table 6

EPA Summary of Expert Panel's Ranking of Stress Agents by Impact on Ecosystems

STRESS AGENTS:	--Freshwater---				---Marine and Estuarine---				----Terrestrial----				
ECOSYSTEMS:	Lakes	Streams	Wetlands - isolated	Wetlands - flowing	Wetlands - saltwater	Estuaries	Near-coastal	Open Ocean	Coniferous Forest	Deciduous Forest	Grassland	Desert/Semi-arid	Alpine/Tundra
Water Sources:													
BOD	Hc l-m	Hc l	M l	M l	M l	Hc l-m	L	-	No Ecological Effect				
toxic organics	Hc m-h	Hc m-h	Hc m-h	Hc m-h	Hc m-h	Hc m-h	Mc m-h	?					
pesticides, herbicides	Hc m-h	Hc m-h	Hc m-h	Hc m-h	Hc m-h	Hc m-h	Mc m-h	?					
chlorination products	H? m-h	H? m-h	H? m-h	H? m-h	H? m-h	H? m-h	M? m-h	?					
toxic inorganics	Hc m-h	Hc m-h	M? m-h	M? m-h	M? m-h	H? m-h	L? m-h	?					
nutrients	M-H l-m	L-M l	M-H l-m	M? l-m	Mc l-m	Hc l	Mc l	-					
microbes	-	-	-	-	-	-	-	-					
turbidity	Lc l	Hc l	L l	L l	L l	Mc l	Hc l-m	-					
acids	Hc m	Hc m	Hc m	Hc m	-	L	-	-					
oil & petroleum products	H? l-m	H? l-m	-	M m	M m	H? l-m	H? l-m	?					
thermal pollution	Mc l-m	Mc l-m	Mc l-m	Mc l-m	Mc l-m	Mc l-m	-	-					
entrainment and impingement	?	?	-	-	-	?	-	-					

Key: | X- |
| x |-----Intensity of ecological effect that potentially could occur.

H = High
M = Medium
L = Low
- = No ecological effect
c = Certain or probable ecological response
? = Uncertain ecological prediction because of insufficient understanding or because of infrequent ecological response

| X |
| x- |-----Time of Ecosystem Recovery once the stress is removed.

l = years (0-10 years)
m = decades (10-100 years)
h = centuries (100-1000 years)
i = indefinite (more than 1000 years)

°FOOTNOTE CONTINUED ON NEXT PAGE

°FOOTNOTE CONTINUED ON NEXT PAGE

Table 6 (Continued)

ECOSYSTEMS:	--Freshwater---				---Marine and Estuarine---				----Terrestrial----				
STRESS AGENTS:	Lakes	Streams	Wetlands - isolated	Wetlands - flowing	Wetlands - saltwater	Estuaries	Near-coastal	Open Ocean	Coniferous Forest	Deciduous Forest	Grassland	Desert/Semi-arid	Alpine/Tundra
Air Sources:													
gaseous phytotoxicants	-	-	?	?	?	-	-	-	Hc m	Hc m	L l	L m	H? m
acid deposition	L-H m	L-H l-m	--M --m	-	-	L m	?	?	Hc m	Hc m	L? l	-	L? m
air deposition of toxics	L h	L h	-	-	-	?	?	?	?	?	?	?	?
greenhouse gases	Hc h-i	Hc h-i	Hc h-i	Hc h-i	Hc h-i	Hc h-i	Hc h-i	?	Hc h-i	Hc h-i	Hc h-i	Hc h-i	Hc h-i
ozone-depleting gases	H?	H?	H?	H?	H?	H?	H?	H?	H?	H?	H?	H?	H?
Terrestrial Sources:													
pesticides & herbicides	?	?	?	?	?	?	?	-	?	?	?	?	?
solid matter	-	-	-	-	-	-	-	-	?	?	?	?	?
toxic organics & inorganics	-	-	-	-	-	-	-	-	?	?	?	?	?
microbes	-	-	-	-	-	-	-	-	?	?	?	?	?
Other Environmental Problems:													
radionuclides	-	-	-	-	-	-	-	-	-	-	-	-	-
habitat alteration	Hc l-i	Hc l-i	Hc l-i	Hc l-i	Hc l-i	Hc l-i	Lc l-i	-	Hc l-i	Hc l-i	Hc l-i	Hc l-i	Hc l-i
introduced species	H?	H?	H?	H?	H?	H?	H?	-	H?	H?	H?	H?	H?
biotechnology	?	?	?	?	?	?	?	?	?	?	?	?	?
groundwater contamination	?	?	?	?	?	?	-	-	-	-	-	-	-

° The ecosystem groupings "lakes", "streams" and freshwater "wetlands - isolated" represent both "buffered" and "unbuffered" categories used by the expert panel. This accounts for the two different potential risks shown for those groupings for the stress agents "nutrients" and "acid deposition."

TABLE 7

	Scale of potential ecological effects		
	biosphere	**regional**	**ecosystem**
High ecological importance	• global climate changes from greenhouse gases (8)	• regionally transported gaseous toxicants (1) • acid deposition (1) • habitat alteration (13-14)	• locally transported gaseous toxicants (1,2) • toxics in surface water (9,10,11,12,21,22,28) • pesticides, herbicides (25) • nutrients (9,10,11) • acid inputs to surface waters (9,10,20) • oil (9,10,11,20,22) • habitat alteration (13-14,20)
Medium ecological importance		• oil (9,10,11,20,22) • toxics in water (9,10,11,16,17,28) • herbicides, pesticides (27)	• B.O.D. (9,10) • turbidity (11,20)
Unknown but potentially very important	• uv-B from ozone depletion (7)	• biotechnology (29)	• groundwater contamination (12,16,17,18,19,20,23,24) • chlorination (9,10)

APPLICATION OF THE RANKING METHODOLOGY

Following the panel evaluation, the workgroup conducted its independent risk assessment of 22 problems, employing much of the panel approach.

Each of the environmental problems was assigned to a work group member or other person, usually someone representing the relevant EPA program office. Following a basic outline, each writer was to prepare a background paper that discussed the ecosystem risks imposed by the assigned environmental problem. The papers were to emphasize sources, exposure levels and risk, both to allow an evaluation of risk and to provide support for the ranking of the problem. Specifically, the writers were directed to:

- Use the same stress agents and ecosystems as the expert panel did;
- Describe the assigned problem's sources and the exposures created by those sources, and estimate the problem's geographic scale (biospheric, regional, or local);
- Assess the ecological impacts of the stresses, including the ability of ecosystems to recover once the stress are removed; (while writers and workgroup members were not required to accept the panel's evaluation of the potential damage from individual stresses to individual ecosystems, the panel's evaluation was given great weight).
- Note the degree that the problem is currently controlled, and the expected level of control in the near future;
- Characterize the quality of available information; and
- Provide an evaluation of the overall importance of the environmental problem.

The workgroup members were asked to review these problem papers and, using the same basic approach as in the problem papers, to provide an aggregate personal ranking for each of the problems. They were urged to base their ranking on information contained in the background papers -- as opposed to their personal perceptions. The workgroup members were provided a blank form that allowed them to develop an aggregate rank based on rankings for each ecosystem. There were no prescriptive instructions on how to assess the seriousness of damage to ecosystems, but members were urged to consider changes in ecosystem structure and function, and time for recovery after removal of stress.

The workgroup met on December 1, 1986, to develop a final consensus ranking. Most individual members' aggregate rankings used a subjective analysis of the information in the background papers, as well as personal knowledge. The information used to develop the background papers was highly variable, resulting in rankings being made on a somewhat unequal data base.

The individual members' rankings of each problem were then tabulated according to an overall classification of the problem as high, medium or low. The workgroup rankings were determined by simple cluster analysis of individual members' rankings, done by visual inspection. While individual members' evaluations of risk from a problem to a particular ecosystem varied somewhat, there was good agreement as to the overall high, medium or low level of risk presented by the problems. The workgroup members then discussed the results of the cluster analysis and reached a consensus ranking, shown in Table 1.

The work group also arrayed the high-medium-low ranking of environmental problems according to the geographic scale of impact -- local, regional and biospheric. This three-by-three matrix is shown in Table 2. The work group found it more difficult to reach a consensus regarding the scale of impact.

After classifying the problems into high, medium, or low categories and establishing geographic impact scales, the workgroup tried to rank the problems within the high, medium and low categories. This proved to be very difficult, primarily because of insufficient information. The workgroup did, nevertheless, group the eight problems in the high category into three rank groupings, and the eight problems in the medium category into two rank groupings, as shown in Table 1.

As indicated previously, three problems - new toxic chemicals, biotechnology and discarded plastics - were not ranked due primarily to uncertainty about the risk presented. As noted above, ocean dumping and incineration were inadvertently omitted from evaluation and ranking.

Part III

OBSERVATIONS AND COMMENTS

This project was designed and carried out to meet specified institutional objectives and needs. As a necessary condition of achieving those objectives, a number of constraints or limitations were imposed on the workgroup; these have been described and discussed in previous portions of this report. In order to fully understand and evaluate the scope and importance of the environmental impacts considered in this report, it is critical to understand the larger environmental context in which these impacts occur and the institutional context which shapes and limits EPA's response to them. These two areas are explored in some detail below, along with a number of comments on methodological problems associated with ranking ecological effects.

THE ENVIRONMENTAL CONTEXT

The stresses and problems this workgroup evaluated do not affect ecosystems one at a time nor within the neat categories to which we have assigned them. Moreover, we have not dealt with all classes or types of stresses to which these systems are being subjected.

Perhaps the single most important stress, which tends to eclipse most of the others for most ecosystems, is the alteration -- including outright destruction -- of habitat. In this evaluation, we considered only a limited subset of this principal threat -- namely, the physical alteration of aquatic habitat and, to a lesser and indirect extent, the impacts that sea level rise, siting of various waste management facilities, and mining have on habitat. Conspicuously absent from this list are the widespread and growing physical impacts of agricultural conversion, silvicultural practices and conversion of mixed mature stands to monocultures, grazing, consumptive removal of surface and ground water, human foot traffic (e.g., hiking trails in fragile alpine areas), general human disturbance and noise, and the construction of highways, housing, factories, shopping centers, and many other structures.

Not only do these direct physical assaults modify or destroy habitat outright, they also tend to make natural communities much more susceptible to stresses engendered by the environmental problems that we evaluated. We know, for example, that fragmented or structurally impaired natural communities lose elasticity and/or resilience and are, therefore, considerably more vulnerable to the effects of toxic pollutants.

Conversely, we also know that ecosystems stressed by pollution are far more vulnerable to the adverse consequences of climatic changes, pests, or the introduction of exotic species. In each of these cases, the reasons for this increased vulnerability are fairly well understood. Natural communities have evolved in intimate relationship with their abiotic environment -- soils, water, and climate -- and have developed complex structural and functional characteristics, such as biogeochemical cycles and food webs that both sustain and define them. Any changes in structure or function due to an external stress upsets the delicate equilibrium inherent in the ecosystem, leading either to increased vulnerability to other stresses or to a shift to a new equilibrium state, or both.

Such impacts may interact additively, synergistically, or antagonistically, but our knowledge in this area is so limited as to generally preclude prediction. The results, however, are more predictable -- depletion of genetic pools, change to another community type (usually a less complex, more impoverished one), loss of substrate, and significant changes in hydrologic cycles, to name a few. Thus, it is critical that we not only keep in mind this larger context as we discuss particular environmental problems, but also that we support those programs of other agencies and levels of government that address the problems that we cannot.

THE INSTITUTIONAL CONTEXT

EPA in practice is much more a "pollution control" agency than an "environmental protection" agency. EPA does not place much emphasis on some of the types of impacts considered by this work group. (A few notable exceptions are to be found in the programs focusing on wetlands, pesticides, and water quality.) Recognizing this reality is critical to fully understanding the results of this effort, since it limits both the data and information necessary for conducting this assessment and EPA's capability to respond to the environmental problems identified.

This situation is not too surprising when one considers the historical roots of EPA and its authorities. In the immediate wake of Earth Day (April 1, 1970), when this agency was formed, the principal popular and political impetus for its creation was the alarming recognition of the impact of toxic chemicals on our environment as detailed in Rachel Carson's Silent Spring. Perhaps of equal importance is the fact that the primary responsibilities for protecting fish, wildlife, forests, and other natural resources were already vested in other agencies, notably the Departments of Interior and Agriculture. Even in the 1970 reorganization, the President and Congress chose to place a numnber of environmental protection responsibilities not in EPA, but in NOAA, an arm of the Department of Commerce. The result was that EPA's initial set of responsibilities was somewhat biased toward the public health side of the spectrum, though significant environmental responsibilities are found in some of our legislation, particularly the water and pesticides laws, and are embodied in the mandates of others.

As new issues emerged and the Congress responded with legislation, the shift away from environmental (i.e., natural ecosystem) emphasis and toward public health protection intensified (with the notable exception of the surface water protection programs). By the early 1980's, it had reached the point that nonhuman health concerns were openly given little regard. While this attitude was far from universal within EPA, it was sufficiently dominant to influence both policy and program development, and it had a clear impact on staff recruitment. Thus, we find ourselves now with an institutional "culture" that subordinates true environmental issues to a poor second, which in a climate of resource constraint frequently equates to simply "falling off the list" completely. Of probably more far-reaching consequence, however, has been the impact of this bias on a variety of EPA activities. Today we find ourselves with a rudimentary data base on actual environmental effects (or even ambient conditions), and we lack the tools and methods needed both to assess environmental effects and to evaluate their consequences.

In the last several years some reversal of this overall trend has been seen, tangible examples being the formation of the Offices of Marine and Estuarine Protection and Wetlands Protection. The change has been attributed to a variety of factors, including the interests of current top management, the emergence of new issues with predominately environmental consequences (for examples, forest decline and the effects of acid deposition on lake fauna), and some popular "rediscovery" of certain issues, such as biotic impoverishment and the threatened loss of entire ecosystems.

Thus, although the effects of this historical bias are probably not permanent, they certainly affect current EPA priority-setting and policy formulation. This was evidenced, for example, by this workgroup's difficulty in locating both data and expertise within EPA for carrying out the evaluation of ecological risk.

It can be argued, perhaps, that this situation may not actually be a problem, given the responsibilities and capabilities of other agencies. If other federal agencies have the primary responsibilities for protecting natural resources, including flora and fauna, why is it critical that EPA play a major role in these areas? We believe that there are important reasons for EPA to strengthen its capability to protect environmental values other than human health.

First, EPA does have a number of direct statutory responsibilities in this regard. In fact, all of EPA's major statutes, except the Safe Drinking Water Act, require EPA in some fashion to take into account pollution effects other than those to humans. In some cases, this may be a very direct and explicit responsibility, such as in section 404 of the Clean Water Act (wetlands protection) or Title I of the Marine Protection, Research and Sanctuaries Act (ocean dumping). In others, it may be much less direct and of obviously lower Congressional priority, such as the national Secondary Ambient Air Quality Standards. Moreover, in most of its activities, EPA like any other Federal agency must comply with a number of externally administered statutes or directives that emphasize protecting the natural environment. These include the Endangered Species Act, the National Environmental Policy Act, and the Executive Orders on Wetlands Protection (E.O. 11990) and Floodplain Management (E.O. 11988).

These responsibilities have not been, and cannot be, delegated to any other agency. More important, they are not generally duplicative of the environmental protection responsibilities of other agencies, since they focus on the protection of the environment primarily from chemical pollution, as opposed to physical manipulation or destruction. Because of the breadth of sources, pollutants, exposure pathways, and ecosystems involved, it is necessary for EPA to maintain a broad expertise and capability to deal with environmental processes and effects in natural communities.

Second, even in those areas where another agency is assigned the primary role of protecting the environment, EPA can and frequently does play an important supporting role to the other agency. This support can take a variety of forms, such as assisting the Department of Agriculture in developing an integrated pest management program for the national forests or rangeland, and in developing regulations to implement the conservation programs of the "Farm Bill" (i.e., the conservation reserve, "sodbuster," and "swampbuster" programs); working with NOAA in establishing marine monitoring and research programs; and reviewing a variety of other agency programs and activities and helping them formulate less environmentally damaging alternatives. These may include highways (DOT), surface mining (DOI), water resource development (Corps of Engineers, USDA/SCS, DOI/Bureau of Reclamation), deep sea mining (NOAA), hydroelectric power development (FERC), and fossil and nuclear energy development (DOE, NRC).

In each of these examples, EPA's important supporting role is based upon its knowledge and expertise in pollution control as applied to natural ecosystems. Not only is our pollution - related expertise necessary to the other agencies in meeting their objectives, but also their expertise and actions help us meet our own broad mandates for protecting the whole environment.

METHODOLOGICAL PROBLEMS

As indicated previously in this report, the work group encountered a number of difficult methodological problems. Some of the problems reflect the very complex nature of evaluating ecosystems, but other problems result from insufficient emphasis throughout the Agency on ecological matters. Summarized below are some of the more critical problems the work group had to deal with.

No Established Methodology Exists for Evaluating Ecological Risks

Most Agency risk assessment activities have dealt with human cancer or other human health problems. This focus on human health, especially on a single disease endpoint (cancer in humans), as well as the focus on the impacts of individual chemicals, facilitated development of quantitative human health risk assessment capabilities. The ecological sciences have not produced -- and may never produce - similar quantitative endpoints.

Ecological risk assessment is emerging as an approach to analyzing environmental problems. However, it is in a conceptual stage and has not produced the needed methods, models, and data bases for routine use. Trying to assess ecological effects by using methods that were developed to address human health impacts (i.e., hazard x exposure = risk) is a reasonable conceptual approach but not an easy task. The earlier approach to impact assessment is less formalized and generally does not use probabilistic, quantitative methods. Instead, likely or possible impacts are characterized in qualitative terms, based on professional scientific judgement.

Ecosystem Science is Complex and Predictive Tools are not Available

Although scientific understanding of ecosystem science has grown considerably in the past few decades, this body of knowledge is not sufficient to be assembled and "scaled up" for this project. Ecosystem science is truly an integrative discipline that is based on understanding of component disciplines (chemistry, physics, biology, etc.). Its relatively recent origin explains why ecosystem science is still at a descriptive stage and has not yet produced a body of generalizable facts. Much is known about individual ecological impact on sites that have been well studied, but such results cannot be generalized. Results from one study at a particular site can not be extrapolated to other sites because understanding at the ecosystem level is just too limited.

The complexity of ecological interactions poses a substantial obstacle to predicting with much certainty the results of specific impacts. This complexity involves the dynamics of each plant and animal population, the relationships among populations in the plant-animal communities, and the interactions of the biota with the abiotic environment. Ecological processes, such as nutrient cycling, are often poorly understood. The complexity of ecosystem science has resulted in a substantial use of scientific judgement to complete this assessment. This violates, to some degree, the intent of strict risk assessment, which is to document the assumptions and data that were used to reach conclusions.

Ecological Risks are Difficult to Define

Ecological risks cannot be characterized using common, easily understood measures, such as mortality (used for cancer risk) or economic terms (used for welfare risks). The broad concept of "ecological integrity" (protecting existing conditions) is too general to apply.

In the absence of standard measures of ecosystem "health" (e.g., measures that are equivalent to diagnosing human disease -- fever, white blood cell count, etc.), a confusing diversity of endpoints have been suggested. The confusion derives, in part, from the fact that the ecological attributes for which public protection is to be provided have not been chosen. Also, scientists have not documented adequately the values of ecological systems and functions. The "fishable" goal that the Clean Water Act supplies for the Nation's surface waters is an example, albeit a limited one, of an environmental endpoint in current use.

Scientific Uncertainties are Inherent in Ecological Risk Assessment

Considerable uncertainty exists in most aspects of ecological risk assessments. This includes: (1) identifying the appropriate component stress agents for each environmental problem; (2) characterizing the sources, emissions, and anticipated regulatory controls; (3) describing the movement and transformation of the stress agents in the environment and their ultimate fate; (4) assessing ecological effects in a comprehensive manner (i.e., direct and indirect effects at various levels of ecological organization -- population, community, and ecosystem -- and spatial and temporal scales); and, (5) estimating the reversibility of impacts in terms of how quickly or whether ecosystem recovery occurs.

Some of those uncertainties are similar to those operative in assessing human health risks (e.g., exposure assessment models). Some are more difficult, such as understanding ecological effects.

Estimating the Exposure of Ecosystems to Stress Agents is Particularly Difficult

As in assessing human health risk, exposure to hazard rather than the hazard itself often controls the final ecological risk estimates. Thus, if exposure is low, potential damage may not occur. Because humans are point-source receptors, estimating how extensively they are exposed to hazards is easier than for ecosystems that may cover large geographic areas. The large size of ecosystems, as well as their heterogeneous characteristics, also mean that exposures can be quite variable spatially, making assessment even more difficult. Also, most ecosystems are composed of many populations of organisms that have differing sensitivities to impacts, so that understanding the exposure to specific parts of the system (e.g., benthic organisms or predators) may be important. Overall, estimating ecosystem exposure is extremely difficult for most of the environmental problems and is a significant cause of risk assessment uncertainty.

Ecological Risk Information is Limited

Because there is no standardized ecological risk assessment methodology, it is not clear what data and information are needed to analyze risks to ecosystems in a consistent manner. Information that does exist is difficult to access because it is normally not assembled in ways that make it readily available and usable. Using data collected for different purposes (e.g., laboratory toxicological data or urban monitoring data) poses additional problems. Most environmental information has not been collected and analyzed in a manner that facilitates (or even permits) analysis of ecological risks (e.g., most monitoring efforts have not been designed to determine exposure to natural ecosystems).

The List of Environmental Problems is Unsuitable for Assessing Ecological Risk

The 31 environmental problems employed in the Comparative Risk Project reflect EPA's current priorities and represent existing EPA programs. Although EPA's statutory responsibility in these areas typically includes protection of both human health and the environment, the EPA regulatory programs (and thus the problem areas of this project) are oriented disproportionately toward human health concerns.

The outcome of ranking ecological risks depends on which problems are considered and how they are described and grouped. A few examples illustrate this point:

- Several major ecological risks are not included on the list because EPA does not have direct statutory authority. (For example, conversion of natural ecosystems through urbanization and agricultural development, timber harvesting policies in National Forests, marine mammal hunting, and introduction of exotic species were not on the list.)

- The size of a risk category tends to affect its ranking. Land-based waste disposal is very finely subdivided into two kinds of Subtitle D landfills, Subtitle C landfills, and abandoned and uncontrolled landfills; this tends to lower each individual rank. On the opposite extreme, all toxic air pollutants make up an extremely broad category.

The National Focus of the Project Overshadows Global and Local Perspectives

Damage may occur at various levels of ecological organization, ranging from harm to plants and animals, to global, biospheric changes. The Comparative Risk Projects's national assessment takes a medium-level cut at the problem and tends to miss the smaller-scale and larger-scale problems. Local impacts, such as loss of endangered species, can be significant; and so can large-scale impacts, such as loss of global genetic diversity. While the national approach is useful for the purposes of this exercise and makes sense for certain categories of risk (e.g., consideration of only health and welfare in the United States) it does not for some kinds of ecological risks, such as those that transcend political boundaries (e.g., migratory birds and fish, impacts to the oceans, atmospheric alteration).

A few examples of the consequence of the national-level assessment are:

- Impacts on the ocean ecosystem tend to be ranked low if only U.S. sources are considered. (As noted above, the workgroup did not evaluate the impacts of ocean disposal.)

- Habitat alteration that is occurring throughout the world and the related loss of genetic diversity were not considered.

- The only global issues evaluated were atmospheric -- stratospheric ozone depletion and global warming -- and the issue of U.S. sources versus global sources was not adequately treated.

Part IV

Appendix A: "Ecosystems Research Center Workshop on Ecological Effects From Environmental Stresses", Cornell University, Dec. 1986

Appendix B: Background Papers for each environmental problem

Appendix A

Ecosystems Research Center
Workshop on Ecological Effects from Environmental Stresses

A Contribution to the EPA Comparative Risk Project's Ecological Risk Workgroup

December 1986

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Preface

The U.S. Environmental Protection Agency (EPA) is conducting a Comparative Risk Project, an *ad hoc*, intra-agency effort seeking to examine the full gamut of environmental risks associated with potential impacts on human health and welfare interests as well as on ecological systems. An important facet of the project has been the examination of a common list of environmental problem areas by each of the groups interested in specific types of effects. One component of the project has been to focus on ecological issues within the Ecological Risk Workgroup -- a group of EPA staff who examined the list of environmental problem areas, estimated the ecological effects of each on a set of ecosystem categories, and ranked the problems with respect to the magnitude of estimated current or projected ecological effects. This EPA group decided to seek outside expertise to conduct an independent evaluation of the potential ecological effects, comment on the ranking scheme and methodology developed by the EPA group, and provide additional comment on the role EPA should play in addressing important ecological issues.

The Ecosystems Research Center (ERC) at Cornell University, an EPA Center of Excellence for ecological research, was asked to assemble such a group of experts in a workshop. This workshop was held at EPA headquarters on 28-29 October 1986, and consisted of 10 scientists, selected to represent the variety of major ecosystem types in the United States, and whose expertise includes ecosystems-level stress ecology. (See Appendix B for the list of participants.) The results of the workshop deliberations are presented in this report, which reflects the consensus of the participants.

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Background

The U.S. Environmental Protection Agency (EPA) has underway an *ad hoc*, intra-agency effort to examine the variety of environmental problems under EPA purview facing the United States with respect to different endpoints of concern, specifically human cancer risks, human non-cancer health risks, welfare effects, and ecological effects. This activity is under the aegis of the Comparative Risk Project, and each category of risk is being evaluated by a separate subgroup of the project looking at a common list of environmental problems. The list of environmental problems was developed by the Comparative Risk Project into the thirty-one categories presented in Table 1.

The particular focus pertinent to this report is on the activities of the EPA Ecological Risk Workgroup, which consists of EPA staff representing a variety of offices in the Agency. That group slightly altered the list of thirty-one by: a) combining items 9 and 10 to include both direct and indirect point-sources into surface waters; b) combining items 25 and 27 to include all risks from pesticides to the environment; c) redefining items 13 and 14 to constitute any direct physical alteration to surface water systems (e.g., dredging and filling); d) expanding item 11 to include in-place toxics in sediments of surface water systems; e) expanding item 20 to include all effects associated with resource extraction; and f) eliminating items 4, 5, 15, 26, 30, and 31 as having no relevance for ecological effects.

The resulting list of environmental problems (see Table 5) was examined by the EPA Ecological Risk Workgroup for effects on ecological systems. A classification scheme for ecosystems was prepared, consisting of fifteen ecosystem types for marine, estuarine, freshwater, and terrestrial ecosystems, plus four additional categories for special issues. The group assigned a qualitative score for estimated effects from each of the environmental problem areas on each of the ecosystem categories; the resulting matrix is included as Appendix A. The EPA group also prepared a set of position papers on most of the environmental problem areas, each consisting of a few-page description of the nature of the problem and some comment on the ecological risks associated with it.

The EPA Ecological Risk Workgroup decided to enlist outside expertise to assist the evaluation of the ecological risks from the environmental problem areas. The Ecosystems Research Center (ERC) at Cornell University was asked to assemble a group of scientists representing expertise in a wide variety of ecosystem types in order to: a) perform an

Table 1

EPA Comparative Risk Project List of Environmental Problems

1.) Criteria air pollutants from mobile and stationary sources - includes acid precipitation

2.) Hazardous/toxic air pollutants

3.) Other air pollutants - e.g., fluorides, total reduced sulfur

4.) Radon - indoor pollution only

5.) Indoor air pollution - other than radon

6.) Radiation - other than radon

7.) Substances suspected of depleting stratospheric ozone layer - e.g., chlorofluorocarbons

8.) CO_2 and global warming

9.) Direct point-source discharges to surface water - e.g., industrial sources

10.) Indirect point-source discharges to surface water - e.g., POTW's

11.) Non-point source discharges to surface water

12.) Contaminated sludge - includes municipal and scrubber sludges

13.) Inputs to estuaries, coastal waters, and oceans from all sources

14.) Inputs to wetlands from all sources

15.) Drinking water at the tap - including chemicals, lead from pipes, biological contaminants, radiation, etc.

16.) Active hazardous waste sites - includes inputs to groundwater and other media

17.) Inactive hazardous waste sites - Superfund; inputs to groundwater and other media

18.) Municipal non-hazardous waste sites - inputs to groundwater and other media

19.) Industrial non-hazardous waste sites - inputs to groundwater and other media

20.) Mining wastes - e.g., oil and gas extraction wastes

21.) Accidental releases of toxics - all media

22.) Accidental oil spills

23.) Releases from storage tanks - includes aboveground and underground storage

24.) Other groundwater contamination - includes septic tanks, road salt, injection wells

25.) Pesticide residues on food eaten by humans or wildlife

26.) Application of pesticides - includes risk to pesticide workers as well as consumers who apply pesticides

27.) Other pesticide risks - including leaching and runoff of pesticides and agricultural chemicals, air deposition from spraying, etc.

28.) New toxic chemicals

29.) Biotechnology

30.) Consumer product exposure

31.) Worker exposure to chemicals

independent evaluation of the potential for ecological effects from each environmental problem; b) critique the methodology and results of the EPA Ecological Risk Workgroup to date in its ecological risk assessments; and c) provide additional comment on the role EPA should play in addressing ecologically important problems that currently are not a major activity within EPA. The EPA group provided the outside experts with the initial EPA ranking of the environmental risks and with copies of the draft position papers covering environmental problem areas 1, 2, 3, 6, 7, 8, 9/10, 11, 12, 13/14, 16, 18, 19, 20, 24, 25/27, 28, and 29.

The ERC workshop group met at EPA headquarters on 28-29 October 1986; the agenda and list of participants are included in Appendix B. The first half-day session was left to the EPA group to overview the environmental problem areas, and to present its methodology and results to date; then the outside expert group met for one and one-half days to conduct its evaluations. Consensus was reached among all of the workshop participants on the approach to be used and on the specific ecological evaluations. The present report reflects that consensus.

Approach

The primary objective of the workshop was to perform an independent evaluation of the environmental problem areas with respect to their potential for ecological effects. Consequently, initial attention was given to the list of environmental problem areas provided by EPA. The workshop was asked to address that specific list in order for its results to be comparable with other evaluations within the Comparative Risk Project. Much discussion focused on the limitations of the list and of the background information supplied to the workshop participants. Specifically, it was clear to the workshop group that the listed problem areas are not categorized in parallel, and that the criteria for selecting the items on the list were not primarily related to potential types of environmental stresses. Consequently, individual categories often contained many different types of environmental stresses. For example, category 1 includes "criteria pollutants", those pollutants identified in the Clean Air Act for which National Ambient Air Quality Standards are required (SO_2, NO_x, O_3, CO, Pb, and particulates). The types of ecological stresses associated with this single category vary widely, from local-scale deposition of a heavy metal whose primary concern is for ecological routes to humans, to the transboundary-scale problem of acid deposition, which has the potential for significant ecological effects on freshwater and terrestrial ecosystems involving pH stress, aluminum toxicity, enhanced susceptibility to disease and pest infestations, differential effects on competitive interactions in ecological communities, and so on. On the other hand, many classes of environmental stresses from anthropogenic activities were categorized into more than one environmental problem area. For example, the potential ecological impacts from xenobiotic organic chemicals that are toxic to biota could be associated with the EPA-listed items 1, 2, 3, 9/10, 11, 12, 16, 18, 19, 20, 21, 22, 23, 24, 25/27, and 28.

The difficulty this situation presented for the ecological workshop participants was that evaluating the relative potential ecological effects from the EPA list of problem areas would require *both:* a) an evaluation of the relative ecological impacts from different environmental stresses, and b) an evaluation of the relative contribution of each stress from the various sources (problem areas) with respect to the magnitude, frequency, duration, form, and spatial distribution of the anthropogenic inputs into the environment. Whereas the workshop participants felt they collectively have the expertise to estimate ecological effects from a variety of ecological stresses (item a), they did not feel competent to evaluate the specific relative contribution of the anthropogenic sources into the environment (item b), and could not fully utilize the briefing materials provided by EPA. Related to item (b), the consensus of the participants was that whereas they received an understanding of the breadth of environmental problems in the United States facing the EPA, they did not gain a sufficiently complete understanding of the relative importances *across* various sources of environmental problems.

Consequently, the workshop participants decided it was not possible to rank the EPA list of environmental problem areas directly without much greater information on sources, but, rather, to focus on item (a), drawing upon their expertise to identify the full range of anthropogenic stresses on ecological systems and to estimate the potential for ecological effects from each type of stress. The task of linking this evaluation back to the initial list of thirty-one problem areas is left to a longer, more concerted research effort in the future.

The workshop participants began from the EPA list as modified by the EPA Ecological Risk Workgroup (Table 5), by identifying the specific types of ecological stresses associated with each item on the EPA list. In addition, a few potential environmental stresses were identified by the ecological workshop participants that were not incorporated in the EPA environmental problems list; these stresses were added to make the final set of stresses more comprehensive and not necessarily limited to activities currently under the purview of EPA. The stress types were categorized by the agent of introduction into the environment (e.g., anthropogenic stresses transported by the atmosphere, inputs transported by surface water systems, etc.). The set of ecological stresses developed by the workshop is presented in Table 2. It should be noted that the categories of stresses are still not fully parallel, and multiple scales of effects often remain associated with a single stress category, as discussed previously with respect to the EPA-generated list. Nevertheless, each category of ecological stresses was selected to represent a common mode of exposure and type of ecological response.

The next step was to select the particular types of ecosystems to consider for potential effects associated with each stress. The criteria for developing the ecosystem categories list were: a) to have as few categories as possible while maintaining sufficient resolution so that differential ecological responses could be assigned, and b) to develop categories that would be readily recognizable by non-specialists. The resultant classification (Table 3) is quite similar to the initial list prepared by the EPA Ecological Risk Workgroup, even though the outside expert group did not use the EPA list as a point of departure. The ecosystem categories differ considerably in the level of detail; in some cases, the characteristics determining ecological responses can be readily identified. For example, for freshwater ecosystems, strong positive correlations generally exist between acid-neutralizing capacity (buffering) and the levels of total alkalinity and limiting nutrients; these in turn determine the sensitivity of the ecosystem to various stresses. Similarly, a distinction between isolated and flow-dominated freshwater wetlands was deemed appropriate, because of well-recognized differences in the hydrologies, loading pathways, and internal properties of these ecosystems; isolated wetlands tend to be less productive, with lower nutrient loadings, less mixing, greater benthic stagnation, and higher levels of phytotoxic, reduced compounds (e.g., hydrogen sulfide) in sediments. It was agreed by the workshop participants that future efforts should concentrate on searching for alternate methods for classifying ecosystems, including an effort at a functional characterization which could incorporate more fully current ecological understanding in designing an ecosystem categorization and which would more readily allow for site-specific factors that could alter the projected stress-response relationships.

Once these categories were agreed upon, the workshop participants considered each anthropogenic stress with respect to the *potential* for ecological effects on each ecosystem type. The approach was to consider the qualities of each ecosystem as a basis for estimating the nature and extent of potential effects if exposure by the ecosystem to the particular stress were to occur. Such a hypothetical approach allowed the workshop not to be unduly limited by an insufficient information base and understanding by the participants concerning the nature of anthropogenic sources. In some cases, the participants felt confident to take source information into consideration in estimating potential ecological effects from particular stresses, but in most cases that was not feasible. Consequently, the resulting assessment is best characterized as representing potential ecological effects rather than reflecting the extant state of the environment. A comprehensive assessment of the ecological risks and damages of anthropogenic activities in the United States would require a much larger effort and much more extensive information base than available here. Nevertheless, the accuracy of the ecological effects projections will improve significantly with increased understanding of the nature and extent of each anthropogenic stress.

Potential ecological effects were estimated first with respect to the scale at which impacts would likely occur: at the biosphere level, at regional (i.e., transboundary, landscape) scales, or only at localized ecosystem levels. A nested scheme was developed, such that an ecological effect expected to occur at the biosphere level, e.g., associated with climatic change issues, would also be expressed as ecological effects at the regional or local ecosystem levels. Consequently, each stress was considered for its specific effect at the ecosystem level using the following factors:

1) the potential intensity of ecological effects, evaluated as high, medium, low, or no effect;

2) the nature of the ecological effect, specifically: a) affecting the biotic community structure, such as alterations in the trophic structure, species diversity or richness, or other community-level indicators of disturbance; b) affecting ecological processes, such as primary production, rates of nutrient cycling, decomposition rates, etc.; c) affecting particular species of direct importance to humans, such as for aesthetic or economic reasons, or affecting endangered or threatened species; and d) the potential for the ecosystem to function as a vector for routes of exposure to humans of chemicals or organisms having potential health-effects concerns;

3) the degree of certainty associated with the projections, differentiating those circumstances where the data and understanding are sufficient for certain or probable projections to be made versus the situation of either poorly understood stress-response relationships or of highly infrequent occurrence of adverse responses; and

4) the probable time scale for recovery to occur following cessation of the stress, estimated as years, decades, centuries, or indefinite time for recovery.

Each of these estimations was based on the collective expertise of the ecological workshop participants, and, thus, relies on the scientific judgment of the participants rather than on actual analyses. Now that the framework for this cross-ecosystem stress evaluation has been established, however, it should be straightforward to extend the ecological risk assignment to include more rigorous analyses and extrapolations from case studies and experimental evidence. Clearly, there was insufficient time at the two-day workshop to undertake that effort, and a continuing research activity would be needed to effect it. The group consensus was that a continuing, second-order effort at refinement by this or a similar group of ecologists is a high priority.

Table 2
ERC Ecological Workshop List of Anthropogenic Ecological Stresses

Stress agents:

Air sources (anthropogenic stresses transported through the atmosphere):

- gaseous phytotoxicants - includes ozone, SO_2, NO_x, etc.
- acid deposition
- air deposition of toxics - includes aerial transport of metals and volatile organics, such as PAHs, PCBs, etc.; particularly important near urban areas from automobile exhaust, fossil fuel combustion, etc.
- greenhouse gases - includes gases that can lead to climatic alterations through changing the solar energy balance of the atmosphere, including CO_2, N_2O, CH_4, CFCs, and other gases.
- ozone-depleting gases - includes gases such as CFCs that can reduce stratospheric ozone and consequently result in increased levels of UV-B radiation.

Water sources (anthropogenic stresses transported through surface water systems):

- B.O.D. - biological (biochemical) oxygen demand.
- toxic organics - toxic organic chemicals from anthropogenic sources; includes PCBs, kepone, PAHs, etc.; in dissolved and particulate states; does not include pesticides and herbicides.
- pesticides and herbicides - includes agricultural biocides that are exported from target agroecosystems through surface water systems.
- chlorination products - includes inorganic chlorine plus organochlorine by-products associated with wastewater treatment.
- toxic inorganics - includes water-borne sources of lead, mercury, copper, cadmium, cyanide, arsenic, selenium, other metals, etc.; does not include acid effects.
- nutrients - nitrogen and phosphorus.
- microbes - human pathogens.
- turbidity - includes only physical effects of particles in surface water systems.
- acids - only includes effects from lowered pH in surface waters; sources include acid mine drainage and industrial effluents.
- oil and petroleum products - includes chronic effects and accidental spills.
- thermal pollution - especially significant source is nuclear power plants; thermal inputs also from other power plants and industry.
- entrainment and impingement - physical effects on individual organisms as taken from aquatic ecosystems into cooling systems of power plants and other industry.

Terrestrial sources (anthropogenic stresses applied directly to terrestrial systems):

- pesticides and herbicides - applications directly to terrestrial ecosystems or by drift from agricultural applications; transport by surface and groundwater systems considered elsewhere.
- solid matter - includes physical effects only (i.e., not chemical effects) from mine spoils, fly ash, solid waste, sludge, etc.
- toxic organics and inorganics - includes metals and organic wastes dumped directly onto land; transport by surface and groundwater systems considered elsewhere.
- microbes - human pathogens in sludge.

Other environmental problems

- radionuclides - inputs to air, water, and terrestrial systems of radioactive chemicals.
- habitat alteration - includes any direct physical alteration to habitats.
- introduced species - deliberate or inadvertent introduction by humans of natural species novel to a particular environment.
- biotechnology - accidental or deliberate releases of engineered organisms into the environment.
- groundwater contamination - includes all contaminants entering groundwater systems, such as metals, toxic organics, toxic inorganics, pesticides, herbicides, radionuclides, and microbes.

Table 3
ERC Ecological Workshop List of Ecosystem Categories

Freshwater ecosystems

- buffered lakes
- unbuffered lakes
- buffered streams
- unbuffered streams

Marine and estuarine ecosystems

- coastal ecosystems
- open ocean ecosystems
- estuaries

Terrestrial ecosystems

- coniferous forests
- deciduous forests
- grassland ecosystems
- desert and semi-arid ecosystems
- alpine and tundra ecosystems

Wetland ecosystems

- buffered freshwater isolated wetlands
- unbuffered freshwater isolated wetlands
- freshwater flowing wetlands
- saltwater wetlands

Results and Discussion

Ecological Effects Evaluations

The results of the workshop deliberations were collated into a matrix (Table 4), which indicates the variety of ecosystem types considered, the variety of anthropogenic stresses considered, the potential intensity of each ecological effect, and the prospects for recovery, with annotation to discuss particular qualifications concerning the effects projections. It is difficult to capture the full range of discussions and deliberations that led to characterization of each cell in this matrix; the footnotes for each cell reflect the discussions, but considerably more depth was associated with the discussions at the workshop for each evaluation. The matrix was developed by examining a single stress with respect to its potential effects across ecosystem types; because of insufficient time, little attention was given to comparisons of a single ecosystem category with respect to relative potential effects from different stresses. Consequently, the matrix is most reliable for comparisons along each matrix row, and comparisons down columns are less reliable.

The workshop participants discussed how each stress agent related to the original EPA list of thirty-one problem areas. As mentioned previously, the consensus was that an insufficient basis was available for the workshop to rank those environmental problem areas directly; however, the workshop was able to identify provisionally which ecological stresses would potentially be associated with each environmental problem area. Another matrix was prepared to assist in making the translation between the two lists, presented as Table 5. Note, however, that the relative contribution by different environmental problem areas (sources) to each ecological stress was not evaluated and cannot be inferred from the matrix in Table 5.

However, the workshop participants felt that, whereas there was insufficient information to evaluate in detail the source aspects of human effects on the environment, they did have some knowledge concerning source terms and felt capable to begin to prioritize across the variety of ecological stresses. Consequently, an initial attempt was made to identify the priority environmental issues facing the United States currently or in the foreseeable future. This estimation was based on subjective judgment of the participants to provide some guidance to EPA with respect to the ecologically most important issues requiring attention.

One difficulty arose in preparing this priorities list, specifically that the environmental stresses considered by the workshop and the environmental problem areas defined by EPA may affect the environment at widely differing scales, ranging from very localized concerns, such as associated with inactive hazardous waste sites regulated under Superfund, to very large-scale concerns, such as global-scale alterations in the climate resulting from anthropogenic inputs of greenhouse gases into the atmosphere. Assigning a relative importance to such widely differing scales of effects is not strictly a scientific issue, but, rather, requires societal judgment of relative importances. For example, associated with such judgments across scales are issues of: 1) the certainty or uncertainty of causal relationships, including the projected intensity, timing, and duration of effect; and 2) the relative ability to establish scientific certainty across scales relative to the probable occurrence and time frame of the effect, given the continuance of the stress. These types of issues could not be explored in the brief workshop period, and a single ranking across scales was not attempted. Consequently, the workshop participants separately prioritized ecological stresses at the three scales, i.e., biosphere, regional or landscape level, and local or ecosystem level. The workshop identified those issues of greatest ecological concern at each scale, defined with respect to the potential intensity of the effect, the nature of the ecological response, the prospects for recovery, the nature of the anthropogenic source, and prospects for mitigation or amelioration of adverse effects. Other issues of great uncertainty, but of potentially great impact, were also highlighted by the workshop. Finally, the numbered items in EPA's environmental problem areas list (as modified) that might be associated with the priority ecological stresses were identified; again, however, the relative contribution from each source to the overall potential ecological effect was not considered. The results from this prioritization exercise are presented in Table 6.

Comments on EPA Approach

The ERC Ecological Effects Workshop participants also discussed the methodology and results of the EPA Ecological Risk Workgroup, although much less attention was given to this task than to the ecological effects evaluations. The EPA approach of examining potential environmental effects across ecosystems and across environmental problem areas is to be commended as a logical approach to make explicit the assumptions and estimations upon which EPA priorities are established and to identify environmental concerns that may be experiencing insufficient attention at present. Comparing human health, welfare, and ecological risks through examination of a common list of environmental problem areas also seems appropriate as a way to make explicit to managers the disparate issues that need to be considered in environmental decision making. Taking the process the next step, i.e., assigning relative importances to the disparate types of risks, however, should not be done by a formalized methodology, and the current EPA approach, to rely on the considered judgment of senior management whose responsibilities are to make those difficult choices, is required.

The specific environmental problem areas examined in the Comparative Risk Project, however, were not selected solely based on considerations of ecological and human effects; in particular, the EPA list is highly non-parallel in its structure and includes items of relevance to administrative, organizational, or political issues. This significantly complicates the task of performing comparative risk assessments. Translating the itemized problem areas into specific stresses that can be properly evaluated requires substantial information concerning the sources of anthropogenic stresses. Comprehensive source characterization would include information on the intensity, duration, and spatial extent and distribution of the stress relative to the distribution and differential sensitivities of ecosystems exposed to the stress. Lack of sufficient information concerning such sources was a significant handicap to the ecological effects workshop, and it would seem that similar problems would apply to examination of other types of risks.

A second problem with the EPA approach is the mixing of risks that occur at tremendously differing scales of exposure and effects. As discussed previously, comparing effects on very localized systems with effects that can transcend national boundaries is difficult and involves issues other than strictly scientific ones. For instance, the large funding provided by Congress for Superfund activities reflects the important political constituency there is in the United States for concerns about possible abandoned toxic waste sites in the districts of virtually every Congressperson. By contrast, it is more difficult to identify the political constituency for concern about hypothetical global problems projected to be manifested in the next several decades, such as increases in UV-B from stratospheric ozone depletion. Weighting local concerns for environmental problems with immediate time frames versus national concerns for environmental problems with very long time frames (by human standards) requires appropriate societal inputs and judgment.

Nevertheless, it is the consensus of the ecological experts that environmental stresses occurring at larger scales are intrinsically of greater ecological concern because: a) such stresses transcend ecological boundaries, exposing resistant and sensitive ecosystems alike, making the potential ecological effects more consequential; b) larger-scale ecological disturbances require greater times for recovery processes and have decreased chances of eventual recovery at all; c) there is a greatly decreased opportunity for mitigation or amelioration of large-scale ecological effects; d) smaller-scale effects, such as at the local ecosystem level, are concomitant with the larger-scale stresses; e) the time constants for delays in ecological effects are increased at larger scales, substantially decreasing the opportunities for useful information feedbacks from demonstrated ecological effects to appropriate management actions; e) larger-scale ecological stresses are more likely to have synergistic effects with other stresses, and the potential for subtle indirect effects may be enhanced; consequently, there is increased probability of surprise effects that become recognized not through predictions, but only after they occur, making regulation difficult or impossible; f) large-scale stresses transcend national boundaries, making them more difficult to manage and regulate effectively; and g) larger-scale anthropogenic stresses on the environment export the ecological risk far from the activities and sources of origination, potentially affecting ecosystems and human populations that are passive victims of others.

The workshop participants expressed concern at one aspect of the methodology initially considered by the EPA Ecological Risk Workgroup. In particular, a draft report was provided to the workshop concerning an attempt to classify ecosystems with respect to their "inertia", "elasticity", and "resiliency". Two major difficulties occur with the approach as presented by EPA: a) The definitions given for these concepts, as measures of ecological response to stress, do not reflect the terms or concepts commonly in use in stress ecology; consequently, considerable confusion results from the assignment of values for each term for each ecosystem type; b) Ecosystems cannot be categorized for their stress-response characteristics independently from consideration of specific stresses. This follows for several ecological reasons, including the nature of the stress regime under which a particular ecosystem type has developed over evolutionary times. For example, a tropical rain forest is very capable of accommodating the ecological perturbation of a species introduction, because the ecological community structure is so complex; on the other hand, the tropical rain forest is very vulnerable to effects of clear-cutting or fires, because so much of the bioavailable nutrients are in living biomass and so little is stored in soil systems; by contrast, a grassland is well adapted to occurrences of fires at particular frequencies, but very sensitive to introduction of an over-grazing species. Many other ecological examples could be illustrated. Consequently, the EPA group's efforts to classify ecosystem types as being very vulnerable, moderately vulnerable, or not very vulnerable, and to assign ecosystem types to a plot of elasticity versus resiliency, without specifying the nature of the stress, are ecologically inappropriate. The ecological effects workshop was informed that this approach had been abandoned by EPA; we here wish to reiterate the need to do so.

The workshop participants did not evaluate in detail the initial rankings performed by the EPA Ecological Risk Workgroup. However, there is concern among the ecological experts that too great an emphasis was given to certain locally important issues, especially potential ecological effects from mining operations, at the expense of insufficient emphasis on larger-scale issues, such as climate alteration and UV-B enhancement. Concern was also expressed about the intent to collapse the EPA ranking matrix to a single value assigned for each environmental problem area. The problems discussed above suggested to the workshop participants that the initial EPA rankings for each cell in the matrix require much more explicit consideration of issues of the scale of inputs, scale of effects, qualitative nature of effects, and relative contributions from each problem area, in order for the rankings to be sufficiently defensible. Adding the effect of aggregation of the rows and columns of the matrix into a single prioritization for the listed environmental problem areas considerably exacerbates the lack of defensibility and reproducibility of results.

The final comment from the workshop participants concerns important environmental issues for which EPA has little or no role in management and protection. The workshop, in its preparation of the list of priorities for ecological stresses (Table 6), recognized three broad categories of primary concern: a) anthropogenic disturbances to the global atmosphere (e.g., greenhouse and ozone-depleting gases); b) anthropogenic inputs of toxic organic and inorganic chemicals; and c) physical alteration of habitats of ecosystems. It is the third category that has the least activity by EPA, primarily for reasons of maintaining land use and water resource management functions at the state level, following a long-standing legal policy in the U.S. and as explicitly directed by the statements of purpose of the Clean Water Act, the Clean Air Act, etc. However, the workshop participants were asked not to restrict their deliberations to EPA-managed or regulated environmental problems. Further, it was clear, from the presentations of the potential ecological impacts from habitat destruction associated with mining operations and with a variety of sources of physical disruption to coastal and wetland systems, that EPA recognizes the potential for very significant and long-lived adverse ecological consequences from physical habitat disturbances; yet, the area of land subject to disruptions from mining alterations is small compared to the area of terrestrial, wetland, and aquatic systems subject to severe habitat alteration through conversion to agricultural uses, urbanization, highway construction, channelization, damming, and similar activities.

The ecological effects workshop was not charged with recommending legislative amendments or initiatives to effect specific new regulatory functions by EPA. However, from an ecological perspective, we can state that, if special ecological concern is recognized for the potential effects of habitat alteration, which is appropriate to do, then it needs to be put into the context of the full range of human activities, not just that subset of activities that currently are under purview of EPA. If the goal is to advance the quality of the national environment through regulation and management of human activities, then one of the most important stresses to regulate is direct alteration of habitat, and this stress is intimately linked to land-use policies.

We believe an ecological basis for evaluating specific ecosystems' responses to specific stresses is provided by the deliberations of the ecological effects workshop. But fully incorporating these inputs into an overall environmental risk assessment could not be done in the time allocated for the exercise thus far. It is the consensus of the workshop participants that a continuing effort would very likely be successful in advancing the scientific basis for ecological risk assessment based on the framework developed at the workshop. Such a continuation project should involve: a) development of an improved methodology for assessing potential ecological effects from stress, rather than relying on an *ad hoc* methodology rushed together in a two-day workshop; b) considerable attention to relating the anthropogenic source terms to the variety of ecological stresses experienced by the environment; c) examination of specific ecological effects from case studies through a concerted cross-ecosystems analysis of stress-responses; and d) continued involvement of the same set of ecological experts, convened periodically to improve the ecological effects evaluations as new information and methodologies become available.

Table 4
ERC Workshop - Ecological Effects Matrix

Note: The ecological effects matrix represents the consensus of the workshop participants concerning the *potential* ecological effects from the various stresses listed. Actual effects experienced by ecosystems would depend on the nature, intensity, duration, and frequency of the stress as applied to each ecosystem. The stress agents listed were selected to represent the full range of ecological stresses that could exist among the EPA thirty-one environmental problem areas. A separate matrix relating the two lists has been prepared (Table 5), but the relative contribution of a particular stress agent from a particular environmental problem area was not addressed by the workshop group. Thus, the group considered the potential ecological effects from toxic organic chemicals transported through surface water systems, as an example, but that same stress could result from industrial effluents, non-point source run-off into streams, municipal or industrial active waste sites, Superfund sites, accidental spills, or other sources.

The ecological effects matrix indicates the potential scale of effect, specifically biosphere, regional, or local ecosystem levels, for each of the stress agents. Details of ecosystem-level effects are then provided, using the scheme as illustrated by the following cell:

Hc	**b,p,s**
cen-ind	**7**

Where:

- Upper left - Intensity of ecological effect that potentially could occur from the listed stress agent, plus an indication of the certainty of the projection.
  - **H** - High ecological effect
  - **M** - Medium ecological effect
  - **L** - Low ecological effect
  - **-** - No ecological effect expected
  - **c** - certain or probable ecological response expected
  - **?** - uncertain ecological prediction because of insufficient ecological understanding or because of infrequent ecological response. Note: this designation does not necessarily suggest a lack of probable effects, but often suggests an inability of the participants to comment on the likely nature or intensity of effects

- Upper right - Type of ecological response
  - b - potential effects on *biotic community* structure
  - p - potential effects on ecological *processes*
  - s - potential effects on *species* of particular importance to humans, specifically economic, aesthetic, or endangered species
  - h - concern for the ecosystem as a potential route to *humans* for health-effects stresses

- Lower left - Time to recovery of the ecosystem once the stress is removed
  - yr - *years*; 0-10 years
  - dec - *decades*; 10-100 years
  - cen - *centuries*; 100-1000 years
  - ind - *indefinite*; > 1000 years

- Lower right - Footnote number.

ecosystems »» stress agents: *air sources*	scale of effect			freshwater ecosystems			
	biosphere	*regional*	*ecosystem*	*buffered lakes*	*unbuffered lakes*	*buffered streams*	*unbuffered streams*
gaseous phytotoxicants		H	H	- -	- -	- -	- -
acid deposition		H	H	L dec 1	Hc b,p,s dec 1	L yr-dec 1	Hc b,p,s yr-dec 1
air deposition of toxics			?	L cen 4	L cen 4	L cen 4	L cen 4
greenhouse gases	H 6, 7	H	H 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7
ozone-depleting gases	H? 8	H?	H? 9	H? 9	H? 9	H? 9	H? 9
water sources							
B.O.D			H	Hc b,p,s yr-dec	Hc b,p,s yr-dec	Hc b,p,s yr	Hc b,p,s yr
toxic organics		M	H	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10
pesticides, herbicides		M	H	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10
chlorination products		M	H	H? b,p,s dec-cen 10	H? b,p,s dec-cen 10	H? b,p,s dec-cen 10	H? b,p,s dec-cen 10
toxic inorganics		M	H	Hc b,p,s,h dec-cen 12	Hc b,p,s,h dec-cen 12	Hc b,p,s,h dec-cen 12	Hc b,p,s,h dec-cen 12
nutrients		M	H	Mc b,p,s yr-dec 14	Hc b,p,s yr-dec 14	Lc yr 14	Mc b,p,s yr 14
microbes			- 16	- h 16	- h 16	- h 16	- h 16
turbidity			H	Lc b,p,s yr 17	Lc b,p,s yr 17	Hc b,p,s yr 18	Hc b,p,s yr 18
acids			H	Hc b,p,s dec	Hc b,p,s dec	Hc b,p,s dec	Hc b,p,s dec
oil and petroleum products		M	H	H? b,p,s yr-dec 23	H? b,p,s yr-dec 23	H? b,p,s yr-dec 23	H? b,p,s yr-dec 23
thermal pollution			M	Mc b,p,s,h yr-dec 22	Mc b,p,s,h yr-dec 22	Mc b,p,s,h yr-dec 22	Mc b,p,s,h yr-dec 22
entrainment and impingement			?	? s	? s	? s	? s

ecosystems **	scale of effect			freshwater ecosystems			
stress agents:	*biosphere*	*regional*	*ecosystem*	*buffered lakes*	*unbuffered lakes*	*buffered streams*	*unbuffered streams*
terrestrial sources							
pesticides and herbicides			? 24	? b,p,s,h 25	? b,p,s,h 25	? b,p,s,h 25	? b,p,s,h 25
solid matter			? 24	- - 28	- - 28	- - 28	- - 28
toxic organics and inorganics			? 24	- - 28	- - 28	- - 28	- - 28
microbes			? 24	- - 28	- - 28	- - 28	- - 28
other environmental problems							
radionuclides	-	- 29	- 29, 30	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30
habitat alteration		H	H	**Hc** b,p,s yr-ind 31	**Hc** b,p,s yr-ind 31	**Hc** b,p,s yr-ind 32	**Hc** b,p,s yr-ind 32
introduced species		H 40	H 40	**H?** b,p,s 40	**H?** b,p,s 40	**H?** b,p,s 40	**H?** b,p,s 40
biotechnology	? 42	? 42	? 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42
groundwater contamination		? 43	? 43	? h 43	? h 43	? h 43	? h 43

ecosystems »»	marine and estuarine ecosystems			terrestrial ecosystems				
stress agents: *air sources*	*coastal*	*open ocean*	*estuaries*	*coniferous forest*	*deciduous forest*	*grassland*	*desert/semi-arid*	*alpine/tundra*
gaseous phytotoxicants	- -	- -	- -	Hc b,p,s dec	Hc b,p,s dec	L yr	L dec	H? b,p,s dec
acid deposition	? s 2	? s 2	L s dec 2	Hc b,p,s dec	Hc b,p,s dec	L? yr	- -	L? dec
air deposition of toxics	? 5	? 5	? 5	? 4, 5	? 4, 5	? 4, 5	? 4, 5	? 4, 5
greenhouse gases	Hc b,p,s cen-ind 7	?	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7
ozone-depleting gases	H? 9	H? 9	H? 9	H? 9	H? 9	H? 9	H? 9	H? 9
water sources								
B.O.D	L	- -	Hc b,p,s yr-dec	- -	- -	- -	- -	- -
toxic organics	Mc b,p,s,h dec-cen 10	?	Hc b,p,s,h dec-cen 10	- - 11	- - 11	- - 11	- - 11	- - 11
pesticides, herbicides	Mc b,p,s,h dec-cen 10	?	Hc b,p,s,h dec-cen 10	- - 11	- - 11	- - 11	- - 11	- - 11
chlorination products	M? b,p,s dec-cen 10	?	H? b,p,s dec-cen 10	- - 11	- - 11	- - 11	- - 11	- - 11
toxic inorganics	L? dec-cen 13	?	H? b,p,s,h dec-cen 13	- - 11	- - 11	- - 11	- - 11	- - 11
nutrients	Mc b,p,s yr 14	- -	Hc b,p,s yr 14, 15	- - 11	- - 11	- - 11	- - 11	- - 11
microbes	- h 16	- h 16	- h 16	- h 16	- h 16	- h 16	- h 16	- h 16
turbidity	Hc b,p,s yr-dec 19	- -	Mc b,p,s yr 20	- - 11	- - 11	- - 11	- - 11	- - 11
acids	- -	- -	L 21	- - 11	- - 11	- - 11	- - 11	- - 11
oil and products	H? b,p,s yr-dec 23	?	H? b,p,s yr-dec 23	- -	- -	- -	- -	Hc b,p,s dec-cen 23
thermal pollution	- -	- -	Mc b,p,s,h yr-dec 22	- - 11	- - 11	- - 11	- - 11	- - 11
entrainment	- -	- -	? s	- -	- -	- -	- -	- -

ecosystems »»	marine and estuarine ecosystems			terrestrial ecosystems				
stress agents:	*coastal*	*open ocean*	*estuaries*	*coniferous forest*	*deciduous forest*	*grassland*	*desert/semi-arid*	*alpine/tundra*
terrestrial sources								
pesticides and herbicides	? b,p,s,h 25	- -	? b,p,s,h 25	? s,h 26	? s,h 26	? s,h 26	? s,h 26	? s,h 26
solid matter	- -	- -	- - 28	?	?	?	?	?
toxic chemicals	- -	- -	- - 28	? h 24	? h 24	? h 24	? h 24	? h 24
microbes	- -	- -	- - 28	? h 24	? h 24	? h 24	? h 24	? h 24
other environmental problems								
radionuclides	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30
habitat alteration	Lc yr-ind 33	- -	Hc b,p,s yr-ind 34	Hc b,p,s yr-ind 35	Hc b,p,s yr-ind 35	Hc b,p,s yr-ind 36	Hc b,p,s yr-ind 37	Hc b,p,s yr-ind 38
introduced species	H? b,p,s 40	- - 41	H? b,p,s 40	H? b,p,s 40	H? b,p,s 40	H? b,p,s 40	H? b,p,s 40	H? b,p,s 40
biotechnology	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42
groundwater contamination	- -	- -	? h 43	- h 44	- h 44	- h 44	- h 44	- h 44

ecosystems »»	wetland ecosystems			
	freshwater - isolated		*freshwater-flowing*	*saltwater*
stress agents: *air sources*	*buffered*	*unbuffered*		
gaseous phytotoxicants	?	?	?	?
acid deposition	- -	M? dec 3	- -	- -
air deposition of toxics	- -	- -	- -	- -
greenhouse gases	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7	Hc b,p,s cen-ind 7
ozone-depleting gases	H? 9	H? 9	H? 9	H? 9
water sources				
B.O.D	M yr	M yr	M yr	M yr
toxic organics	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10
pesticides, herbicides	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10	Hc b,p,s,h dec-cen 10
chlorination products	H? b,p,s dec-cen 10	H? b,p,s dec-cen 10	H? b,p,s dec-cen 10	H? b,p,s dec-cen 10
toxic inorganics	M? dec-cen	M? dec-cen	M? dec-cen	M? dec-cen
nutrients	Mc yr-dec 14	H? b,p,s yr-dec 14	M? yr-dec 14	Mc yr-dec 14
microbes	- h 16	- h 16	- h 16	- h 16
turbidity	L yr	L yr	L yr	Mc b,p,s yr
acids	Hc b,p,s dec	Hc b,p,s dec	Hc b,p,s dec	- -
oil and products	- -	- -	M b,p,s dec	M b,p,s dec
thermal pollution	Mc b,p,s,h yr-dec 22	Mc b,p,s,h yr-dec 22	Mc b,p,s,h yr-dec 22	Mc b,p,s,h yr-dec 22
entrainment	- -	- -	- -	- -

ecosystems »»	wetland ecosystems			
stress agents:	*freshwater - isolated*		*freshwater-flowing*	*saltwater*
	buffered	*unbuffered*		
terrestrial sources				
pesticides and herbicides	? b,p,s,h 27	? b,p,s,h 27	? b,p,s,h 27	? b,p,s,h 27
solid matter	- - 28	- - 28	- - 28	- - 28
toxic chemicals	- h 28	- h 28	- h 28	- h 28
microbes	- h 28	- h 28	- h 28	- h 28
other environmental problems				
radionuclides	- h 29, 30	- h 29, 30	- h 29, 30	- h 29, 30
habitat alteration	**Hc** b,p,s yr-ind 39	**Hc** b,p,s yr-ind 39	**Hc** b,p,s yr-ind 39	**Hc** b,p,s yr-ind 39
introduced species	**H?** b,p,s 40	**H?** b,p,s 40	**H?** b,p,s 40	**H?** b,p,s 40
biotechnology	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42	? b,p,s,h 42
groundwater contamination	? h 43	? h 43	? h 43	? h 43

Table 4 Footnotes:

1.) Recovery time linked to residence time, watershed source time, and biotic and sediment memory.

2.) Potential effects on anadromous fish populations, especially on early stages in life cycles.

3.) Potential effects on waterfowl populations resulting from effects on food resources.

4.) A primary concern is Pb from automobile exhaust; also potential ecological effects from Hg and certain toxic organics.

5.) Currently at global level are demonstrated changes in background levels of Pb and other metals plus detectable amounts of xenobiotic organics; effects on ecosystems unknown.

6.) Ecological effects are certain to occur because the stress will be severe, even if all sources of greenhouse gases are immediately eliminated; timing of effects will be delayed.

7.) Scenario considered: 3-4°C increase globally and 25-40% reduction in precipitation; greater effects at higher latitudes; ecological effects are certain to occur because of the magnitude of the stress, but specific ecological responses are uncertain.

8.) EPA scenario of UV-B increase by 20% by the year 2050 because of catalytic effect of CFCs on stratospheric ozone; more recent projections, based on ozone holes over Antarctica and perhaps the Arctic plus new data from Switzerland suggest UV-B increases may be more severe than this scenario.

9.) Effects from increased UV-B levels are almost certain to occur for all ecosystem types, but specific ecological responses uncertain.

10.) Intensity and duration of ecological effect function of toxicity, persistence, fate-and-transport, partitioning, and bioaccumulation of the chemical in the ecosystem.

11.) Effects from aerial, terrestrial, and groundwater inputs are considered separately; thus, because of the way the sources are defined, these water sources are not stress agents for these ecosystems.

12.) Buffered aquatic ecosystems somewhat less sensitive than unbuffered ecosystems, but potential ecological effects still high.

13.) Metals persist in sediments, but metal toxicity tends to be less than organic toxicity, metals may be less bioavailable, and metal bioaccumulation is less likely to occur as the toxin is transferred through trophic chains.

14.) Responses to nutrient additions are a function of nutrient status of the ecosystem plus the ratio of N:P in the inputs

15.) Water residence time and the relative contribution of riverine water to the estuary are important factors in determining ecological effects.

16.) No ecological effects from these pathogens are likely; concern is for the ecosystem as a route for exposure to humans.

17.) Effects on aquatic ecosystems primarily result from reduced sunlight throughout the water column.

18.) Ecological effects are primarily from smothering of benthos.

19.) Ecological effects can be very significant for coral reef ecosystems and shallow macrophyte communities; effect on coastal ecosystems is a function of water depth, distance from source, and current velocities.

20.) Level of ecological effect related to natural turbidity levels.

21.) Ecological effects on estuaries are very localized; acid swamp drainage in North Carolina has shown estuarine damage.

22.) Ecological effects are highly localized, and vary with season and latitude; elevated water temperature may enhance the spread of human pathogens.

23.) Source includes both chronic releases and accidental spills of petroleum products into the environment. Ecological effects from chronic inputs are not well known; effects from spills are highly variable; the type of oil spilled is important to determining ecological effects; recovery time may vary with type and duration of exposure.

24.) Effects on ecosystems are very localized.

25.) Direct drift from agricultural applications is the only source considered; exposures to agricultural biocides transported through atmospheric, surface water, or groundwater systems are considered elsewhere.

26.) Ecological effects from drift are uncertain, but likely to be localized, with important ecological effects primarily involving biocides affecting non-target organisms; also of concern, route to humans.

27.) The primary source is for insect control.

28.) Effects from leachate are considered elsewhere, associated with water and groundwater sources.

29.) There are no demonstrated ecological effects from routine emissions; ecological concern is limited to route to humans.

30.) Very locally, accidental releases can result in ecologically significant doses (e.g., Chernobyl).

31.) Examples of physical habitat alteration for lake ecosystems are filling and dredging, shoreline construction, and sedimentation.

32.) Examples of physical habitat alteration for stream ecosystems are channelization, dredging, filling, shoreline construction, changes to watersheds, and changes to the hydrologic regime.

33.) Localized ecological effects can occur, such as from causeway construction, sand and gravel mining, or loss of sediment load from upstream dams.

34.) Examples of physical habitat alteration for estuarine ecosystems include dredging and filling, upstream dam construction, shoreline stabilization, and changes to the watershed.

35.) Examples of physical habitat alteration for forest ecosystems include silviculture, mining, conversion to agriculture, urbanization, highway construction, and flooding from dams.

36.) Examples of physical habitat alteration for grassland ecosystems include irrigation and conversion to agriculture, mining, urbanization, and highway construction.

37.) Examples of physical habitat alteration for arid and semi-arid ecosystems are irrigation and conversion to agriculture, urbanization, mining, and highway construction.

38.) Examples of physical habitat alteration for alpine and tundra ecosystems are pipeline construction, mining, oil exploration, and highway construction.

39.) Examples of physical habitat alteration for wetland ecosystems are dredging and filling, water diversion, phosphate mining, conversion to agriculture, and urbanization.

40.) Species introductions occur frequently, usually with little ecological consequences; however, infrequently such introductions result in serious ecological effects; examples include gypsy moth infestations of forests, loss of complete populations of important tree species from chestnut blight and Dutch Elm disease, invasions of fire ants in the Southeastern U.S., outbreaks of starling populations, overgrazing by domestic animals, etc.

41.) Introductions into the open ocean are only a problem for continuous introductions, such as following construction of a sea-level canal between the Atlantic and Pacific Oceans.

42.) There is a remote likelihood of establishment in the open environment of engineered organisms accidentally released from laboratories, but much higher probability of successful establishment of deliberate releases of organisms designed to survive in the environment; low probability of ecological effects of deliberate releases, but potential for extremely significant consequences affecting natural microbial species and critical ecosystem processes.

43.) Ecological effects are limited to localized areas of groundwater reaching surface water systems; even then, ecological effects are highly unlikely unless groundwater is the major source to the aquatic system; the primary concern is route to humans.

44.) Potential route to humans is uptake of contaminated groundwater through the deep root systems of trees, and subsequently entering food chains.

Table 5
ERC Ecological Effects Workshop
Matrix Relating Ecological Stresses with EPA List of Environmental Problems

The list of ecological stresses prepared by the ecological effects workshop is related in this matrix to the potential sources for each stress from the list of environmental problem areas prepared by EPA. The relative contribution of each source to each stress cannot be inferred from this matrix, nor can the number of entries in a column be used to infer any comment about the significance or magnitude of the source. The matrix is intended to assist EPA in its next step in the evaluation process, specifically focusing on the anthropogenic source terms to characterize much more fully the relative magnitude, spatial extent, frequency of occurrence, and other issues concerning importance of each source. Once that source characterization process is accomplished, the ecological effects detailed in Table 4 can be related to the environmental problem areas identified by EPA.

ERC Workshop x-Matrix

environmental problem areas »»	1	2	3	4	5	6	7	8	9/10	11	12	13/14	15	16	17	18	19
stress agents:																	
air sources																	
gaseous phytotoxicants	•	•															
acid deposition	•																
air deposition of organics and metals	•	•	•														
greenhouse gases								•									
ozone-depleting gases							•										
water sources																	
BOD									•	•	•						
toxic organics									•	•	•						
pesticides, herbicides																	
chlorination products									•								
toxic inorganics									•	•	•						
nutrients									•	•	•						
microbes									•		•						
turbidity									•	•							
acids									•					•	•		
thermal pollution									•								
entrainment and impingement																	
oil and petroleum products									•	•							
terrestrial sources																	
pesticides and herbicides																	
solid matter - sludge,mine spoils,etc											•					•	•
toxic organics and inorganics											•			•	•	•	•
microbes											•						
other environmental problems																	
radionuclides		•				•											
habitat alteration												•					
introduced species																	
biotechnology																	
groundwater contamination											•			•	•	•	•

NOTE: This matrix is to indicate potential sources for the ecological stress agents from among the EPA list of 31 environmental problem areas. The magnitude of sources, relative contribution to the stresses, and ecological importance of each environmental problem area cannot be inferred from this matrix.

ERC Workshop x-Matrix

20	21	22	23	24	25/27	26	28	29	30	31	not listed		««environmental problem areas
													stress agents:
													air sources
													gaseous phytotoxicants
													acid deposition
	●						●						air deposition of organics and metals
													greenhouse gases
													ozone-depleting gases
													water sources
													BOD
	●	●					●						toxic organics
	●				●								pesticides, herbicides
													chlorination products
●	●						●						toxic inorganics
●													nutrients
													microbes
●													turbidity
●	●												acids
											●		thermal pollution
											●		entrainment and impingement
●		●											oil
													terrestrial sources
	●				●								pesticides and herbicides
●													solid matter - sludge,mine spoils,etc
●	●	●					●						toxic organics and inorganics
													microbes
													other environmental problems
●	●												radionuclides
●											●		habitat alteration
											●		introduced species
								●					biotechnology
●			●	●	●		●						groundwater contamination

Table 5
Key for Modified List of Environmental Problems

1.) Criteria air pollutants from mobile and stationary sources - includes acid precipitation

2.) Hazardous/toxic air pollutants

3.) Other air pollutants - e.g., fluorides, total reduced sulfur

4.) Radon - indoor pollution only - NOT CONSIDERED BY ECOLOGICAL WORKSHOP

5.) Indoor air pollution - other than radon - NOT CONSIDERED BY ECOLOGICAL WORKSHOP

6.) Radiation - other than radon

7.) Substances suspected of depleting stratospheric ozone layer - e.g., chlorofluorocarbons

8.) CO_2 and global warming

9 and 10.) Direct and indirect point-source discharges to surface water - e.g., industrial sources, POTWs

11.) Non-point source discharges to surface water plus in-place toxics in sediments

12.) Contaminated sludge - includes municipal and scrubber sludges

13. and 14.) Physical alteration of aquatic habitats - e.g., dredge and fill

15.) Drinking water at the tap - including chemicals, lead from pipes, biological contaminants, radiation, etc. - NOT CONSIDERED BY ECOLOGICAL WORKSHOP

16.) Active hazardous waste sites - includes hazardous waste tanks; inputs to groundwater and other media

17.) Inactive hazardous waste sites - Superfund; inputs to groundwater and other media

18.) Municipal non-hazardous waste sites - inputs to groundwater and other media

19.) Industrial non-hazardous waste sites - inputs to groundwater and other media

20.) Mining wastes - e.g., oil and gas extraction wastes

21.) Accidental releases of toxics - all media

22.) Accidental oil spills

23.) Releases from storage tanks - includes product and petroleum tanks; aboveground and underground

24.) Other groundwater contamination - includes septic tanks, road salt, injection wells, etc.

25. and 27.) Pesticide residues on food eaten by humans or wildlife and other pesticide risks - including leaching and runoff of pesticides and agricultural chemicals, air deposition from spraying, etc.

26.) Application of pesticides - includes risk to pesticide workers as well as consumers who apply pesticides - NOT CONSIDERED BY ECOLOGICAL WORKSHOP

28.) New toxic chemicals

29.) Biotechnology

30.) Consumer product exposure - NOT CONSIDERED BY ECOLOGICAL WORKSHOP

31.) Worker exposure to chemicals - NOT CONSIDERED BY ECOLOGICAL WORKSHOP

Table 6
ERC Ecological Effects Workshop
Environmental Stresses Priorities List

The ecological effects workshop identified the potential effects on various ecosystems from a number of stress agents. These stresses do not correspond directly to EPA's list of 31 environmental problem areas (sources), but, rather, require translation through understanding the relative contributions of each source to each stress type. Insufficient information was available to the workshop group to do that translation; however, the group did identify the most important environmental stresses at the biosphere, regional, and local scales. As in Table 4, these scales are nested; i.e, a major effect at a higher scale implies effects also at the lower scales (e.g., a high effect on the biosphere will include potentially high effects on regional and local scales). These priority stresses are listed here, along with the numbers of the associated sources as listed on EPA's list. No inference can be made concerning priorities for the EPA-listed sources, however. For example, toxic organics in surface water systems was identified as a major concern at the local ecosystem level, but those chemicals could have come from listed items 9, 10, 11, 12, 21, 22, or 28; the relative contribution of these sources is unknown to the workshop group.

	Scale of potential ecological effects		
	biosphere	**regional**	**ecosystem**
High ecological importance	• global climate changes from greenhouse gases (8)	• regionally transported gaseous toxicants (1) • acid deposition (1) • habitat alteration (13-14)	• locally transported gaseous toxicants (1,2) • toxics in surface water (9,10,11,12,21,22,28) • pesticides, herbicides (25) • nutrients (9,10,11) • acid inputs to surface waters (9,10,20) • oil (9,10,11,20,22) • habitat alteration (13-14,20)
Medium ecological importance		• oil (9,10,11,20,22) • toxics in water (9,10,11,16,17,28) • herbicides, pesticides (27)	• B.O.D. (9,10) • turbidity (11,20;
Unknown but potentially very important	• uv-B from ozone depletion (7)	• biotechnology (29)	• groundwater contamination (12,16,17,18,19,20,23,24) • chlorination (9,10)

Appendix A

EPA Ecological Risk Workgroup Initial Ranking

The EPA Ecological Risk Workgroup prepared an initial ranking of the EPA list of environmental problems (as modified; see Table 5) with respect to estimated ecological effects on a set of ecosystem categories prepared by the EPA Workgroup. This matrix is presented here. The column labeled "Initial Overall Ranking" was prepared prior to and independently from the rest of the matrix; consequently, it is not intended to be an aggregation across rows in the ranking matrix. The EPA ranking scheme was not considered by the Ecological Effects Workshop when it prepared its effects matrix (Table 4).

EPA Ecological Risk Workgroup Ranking

EPA Environmental Problem	*Marine & Estuarine Ecosystems*				*Freshwater Ecosystems*			
	deep ocean	coastal	estuaries	tidal wetlands	cold streams	warm streams	lakes	wetlands
1	-	-	L	L	L	L	H	L
2	-	L	M	M	L	L	H	L
3	-	-	-	-	-	-	-	-
4								
5								
6	-	-	U	U	U	U	U	U
7	M	L	-	-	-	-	L	-
8	-	M	H	H	U	U	U	U
9	-	M	H	H	H	H	H	H
10	-	M	H	H	H	H	H	H
11	-	M	H	H	H	H	H	H
12	L	M	L	L	L	L	L	M
13	-	M	H	H	H	H	M	H
14								
15								
16	-	L	L	L	L	L	L	L
17	-	L	M	M	M	M	H	M
18	-	L	L	M	L	L	L	M
19	U	L	L	M	L	L	L	M
20	L	H	H	H	H	H	L	H
21	-	L	L	L	H	H	M	L
22	L	M	H	H	L	L	L	L
23	-	-	-	L	L	L	L	L
24	-	-	L	L	L	L	M	M
25	-	-	H	H	H	H	H	H
26								
27								
28	-	-	L	L	M	M	U	-
29	U	U	U	U	U	U	U	U
30								
31								

KEY:		
	-	no effect
	U	unknown
	L	low
	M	medium
	H	high
	(blank)	not rated

EPA Ecological Risk Workgroup Ranking

EPA Environmental Problem	*Terrestrial Ecosystems*								*Special Features*			*Initial Overall Ranking*
	tundra	boreal forest	deciduous forest	grass-land	deserts	subalpine forest	tropical forest	special zones	soil	vulnerable species	migratory birds	
1	U	H	M	L	L	M	L	-	H	L	-	H
2	L	L	L	L	L	L	L	L	L	M	M	H
3	-	-	L	-	-	L	L	-	-	-	-	H
4												
5												
6	U	U	L	U	L	L	U	-	L	-	-	L
7	-	-	-	-	-	-	-	U	-	-	-	L
8	U	U	U	U	U	U	U	U	U	U	U	M
9	-	-	-	-	-	-	-	U	-	H	L	H
10	-	-	-	-	-	-	-	U	-	H	L	H
11	-	-	-	-	-	-	-	U	-	H	L	H
12	-	L	L	M	-	L	L	U				H
13	-	-	-	-	-	-	-	U				H
14												
15												
16	-	-	-	-	-	-	-	U	L	L	-	L
17	-	L	L	L	L	L	L	L	L	L	-	M-H
18	L	L	L	L	L	L	L	L	L	L	-	M
19	H	L	L	L	L	L	L	L	L	L	-	M
20	H	H	H	H	H	H	H	H	H	H	H	H
21	U	-	-	-	-	-	-	L	L	L	-	H
22	U	-	-	-	-	-	-	U	-	M	M	M
23	-	-	-	-	-	-	-	-	L	-	-	L
24	U	U	U	U	U	U	U	L	L	L	-	M
25	U	H	H	H	H	H	H	H	H	H	H	H
26												
27												
28	-	U	U	U	U	U	U	U	-	U	U	M
29	U	U	U	U	U	U	U	U	U	U	U	M
30												
31												

KEY:		
	-	no effect
	U	unknown
	L	low
	M	medium
	H	high
	(blank)	not rated

Appendix B

ERC Workshop on Ranking of Environmental Problems
Agenda

Tuesday, 28 October 1986

0900	Convene Joint Session of Outside Expert Group plus EPA Ecological Risk Workgroup
0900 - 0915	Objectives of Workshop - Harwell
0915 - 1200	Background briefings by EPA personnel • Overview of Comparative Risk Project • Previous work by Ecological Risk Workgroup • Overview of Environmental Problems List Discussions • Critique of previous EPA work
1200 - 1330	Lunch
1330 - 1800	Discussions within Outside Expert Group • Agreement on methodology to be used • Refinement of environmental problems list • Agreement on ecosystem categories • Agreement on criteria for ecological effects
evening	informal discussions to continue in small groups at and after dinner

Wednesday, 29 October 1986

0900 - 1200	Continuation of discussions within Outside Expert Group • Develop environmental stress/ecosystem effects matrix • Assign relative ranking for environmental problems list
1200 - 1330	Lunch
1330 - 1530	Continuation of discussions within Outside Expert Group • Finalize rankings • Discuss EPA role re most important environmental problems
1530 - 1700	Joint Session of Outside Expert Group plus EPA Ecological Risk Workgroup • Report on consensus of Outside Expert Group
1700	Adjourn

ERC Ecological Effects Workshop
Attendees

Dr. Mark A. Harwell, Ecosystems Research Center, Cornell University, Ithaca, New York - Chairperson

Dr. Jim Detling, Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, Colorado

Dr. Katherine Ewel, Department of Forestry, University of Florida, Gainesville, Florida

Dr. Robert Friedman, Office of Technology Assessment, U.S. Congress, Washington, D.C.

Dr. W. Frank Harris, Division of Biotic Systems and Resources, U.S. National Science Foundation, Washington, D.C.

Dr. Robert Howarth, Section of Ecology and Systematics and Ecosystems Research Center, Cornell University, Ithaca, New York

Dr. John R. Kelly, Ecosystems Research Center, Cornell University, Ithaca, New York

Dr. Michael Pilson, Marine Ecosystem Research Laboratory, University of Rhode Island, Kingston, Rhode Island

Dr. John Schalles, Department of Biology, Creighton University, Omaha, Nebraska

Dr. Richard Wiegert, Department of Zoology, University of Georgia, Athens, Georgia

Ms. Roxanne Marino, Section of Ecology and Systematics and Ecosystems Research Center, Cornell University, Ithaca, New York - rapporteur

Appendix B

105
106 ✓

Background Papers for Environmental Problems

1. Criteria air pollutants from mobile and stationary sources -- include acid precipitation

2. Hazardous/toxic air pollutants

6. Radiation - Other than radon

7. Substances suspected of depleting stratospheric ozone layer (e.g., chlorofluorocarbons)

8. CO_2 and global warming

9/10. Direct and indirect point-source discharges to surface waters (e.g., POTWs, industrial discharges)

11. Nonpoint-source discharges to surface water, plus in place toxics in sediment

12. Contaminated sludge - includes municipal and scrubber sludges

13/14. Physical alteration of aquatic habitat (e.g., dredge and fill)

16. Active hazardous waste sites - includes hazardous waste tanks

17. Inactive hazardous waste sites - Superfund

18. Municipal nonhazardous waste sites

19. Industrial nonhazardous waste sites

20. Mining wastes (e.g., coal, oil and gas)

21. Accidental releases of toxics - to all media

22. Accidental oil spills

23. Releases from underground storage tanks - includes product and petroleum tanks; above ground and underground

24. Other groundwater contamination - includes septic tanks, road salt, injection wells

25/27. Pesticide residues on food eaten by humans or wildlife; other pesticide risks - includes leaching and runoff of agricultural chemicals, air deposition of spraying

28. New toxic chemicals

29. Biotechnology

30. Consumer product exposure - limited to ecological effects of plastic material

OAQPS:11/86 #1

OZONE AND ACID DEPOSITION: ECOSYSTEMS EFFECTS

I. Overview

Based on the most recent scientific assessment of ozone and its impacts on forests and natural ecosystems prepared by EPA's Office of Research and Development and reviewed and accepted by the Agency's Science Advisory Board, significant potential and existing effects are associated with stress due to ozone. Ozone, the most pervasive air pollution problem in the United States, is generally considered the most phytotoxic air pollutant adversely affecting vegetation in biotic ecosystems. Stresses placed on biota and the ecosystems of which they are a part can produce changes that are long lasting and that may be irreversible. Ozone is the product of the photochemical reaction of precursor pollutants, mainly volatile organic compounds (VOC) and oxides of nitrogen (NO_x). These precursors are emitted by thousands of sources distributed across the country.

Although the available data on acid deposition effects is more uncertain than that for ozone, there is evidence of damage to ecological systems, particularly aquatic systems. The acid deposition stress agents (compounds of sulfur and nitrogen) are emitted in large quantities in the United States and Canada, and can be transported for hundreds of miles. Ecosystems in areas where the buffering capacity of soil and water is low are particularly susceptible. These areas include the upper Midwest, the Northeast, Southeast, and some areas in the Western mountains. About 10 percent of the lakes in these areas have pH levels less than 5.0.

Because of the very high level of emissions, the broad geographic coverage of potential impacts, and the significance of observed effects (particularly for ozone), criteria air pollutants (viz. phytotoxic and acid deposition) should be ranked as having high ecological risk.

II. OZONE

Sources of Stress

Photochemical production of ozone depends both on the presence of precursors, volatile organic compounds (VOCs) and nitrogen oxides (NO_x), emitted by manmade and by natural sources; and on suitable conditions of sunlight, temperature, and other meteorological factors. Because of the intervening requirement for meteorological conditions conducive to the photochemical generation of ozone, emission inventories are not as direct predictors of ambient concentrations of secondary pollutants such as ozone and other oxidants as they are for primary pollutants.

Emissions of manmade VOCs (excluding several relatively unreactive compounds such as methane) in the United States have been estimated at 19.9 teragrams per year (Tg/yr) for 1983 (U.S. Environmental Protection Agency, 1984). Retrospective estimates show that manmade VOC emissions rose from about 18.5 Tg/yr in 1940 to about 27.1 Tg/yr in 1970 (U.S. Environmental Protection Agency, 1986). An examination of trends in manmade VOC emissions for 1970 through 1983 shows that the annual emission rate for manmade VOCs decreased some 26 percent during this period. The main sources nationwide are larger industrial processes, which emit a wide variety of VOCs, such as chemical solvents; moderate to small processes, such as dry cleaning; and transportation, which includes the emission of VOCs from gasoline handling as well as in gasoline combustion products. Estimates of biogenic emissions of organic compounds in the United States are highly inferential but data suggest that the yearly rate is the same order of magnitude as manmade emissions. Most of the biogenic emissions actually occur during the growing season, however, and the kinds of compounds emitted are different from those arising from manmade sources.

Effects

The responses to ozone of individual species and subspecies of herbaceous and woody vegetation are well documented. They include (1) injury to foliage, (2) reductions in growth, (3) losses in yield, (4) alterations in reproductive capacity, and (5) alterations in susceptibility to pests and pathogens, especially "stress pathogens" (National Research Council, 1977; U.S. Environmental Protection Agency, Criteria Documents 1978, 1986).

Evidence indicates that any impact of ozone on ecosystems will depend on the responses to ozone of the producer community. Producer species (trees and other green plants) are of particular importance in maintaining the integrity of an ecosystem, since producers are the source, via photosynthesis, of all new organic matter (energy/food) added to an ecosystem. Any significant alterations in producers, whether induced by ozone or other stress, can potentially affect the consumer and decomposer populations of the ecosystem, and can set the stage for changes in community structure by influencing the nature and direction of successional changes with possibly irreversible consequences.

There are a substantial number of studies documenting adverse impacts from ozone and other air pollutants on the ecosystem and its biotic components. Tables 1 and 2, taken from the U.S. EPA 1986 ozone criteria document, summarize a number of these studies associated with ozone damage to vegetation.

Ozone-induced effects on the growth of trees has been clearly demonstrated in controlled studies. For example, Kress and Skelly (1982) showed the following reductions in growth in height in seedlings exposed to ozone for 6 hr/day for 28 days: American sycamore, 9 percent (0.05 ppm O_3); sweetgum, 29 percent (0.10 ppm O_3); green ash, 24 percent (0.10 ppm); willow oak, 19 percent (0.15 ppm O_3); and sugar maple, 25 percent (0.15 ppm). Similar results have been obtained for other tree species by other investigators.

Exposures of trees and other producers to ozone have been shown to reduce photosynthesis in numerous studies and to alter carbohydrate allocation, expecially the partitioning of photosynthate between roots and tops. Krause et al. (1984) have associated growth reductions in ozone-exposed seedlings with foliar leaching. All three of these effects have been postulated as mechanisms of the reduced growth seen in ozone-exposed vegetation.

Reductions in the growth of annual rings observed in ponderosa, Jeffrey, and eastern white pine have been attributed to the exposure of the trees to O_3 over a period of 10 to 20 years. Decline and dieback of red spruce in the northeastern United States and reduced growth rates of red spruce, balsam fir, and Fraser fir in central West Virginia and western Virginia also have been attributed to stresses, to which air pollution is a possible contributor, that began at least 20 years ago.

Evidence for the effects of ozone on other ecosystem components indicates that most are indirect, occurring chiefly as a result of the direct effects of ozone on trees and other producers. Significant alterations in producer species can change the ability of a species to compete and thus can influence the nature and direction of successional changes in the ecosystem.

Treshow and Stewart (1973) conducted one of the few studies concerned with the impact of air pollution on native herbaceous species in natural plant communities. The aim of the study was to determine the concentration of ozone necessary to cause foliar injury to the most prelevant species in some of the intermountain grassland, oak, aspen, and conifer communities. Seventy common plant species indigenuous to those communities were fumigated with ozone to establish sensitivity.

In the aspen community, the most dramatic example was aspen (Populus tremuloides (Michx.) itself. A single 2-hour exposure to 0.15 ppm ozone caused severe symptoms on 30 percent of the foliage. Because white fir seedlings require aspen shade for optimal juvenile growth, the authors suggested that significant losses in aspen populations might restrict white fir development and later forest succession; conversion to grasslands could occur. It was apparent that in a natural community exposed to ozone, the tolerant species would soon become the dominants. The authors concluded that ozone must be considered a significant environmental parameter that influences the composition, diversity, and stability of natural plant communities and that it "may ultimately play a major role in plant succession and dominance".

One of the most thoroughly studied ecosystems in the United States is the mixed-conifer forest ecosystem in the San Bernardino Mountains of southern California. Sensitive plant species there began showing injury in the early 1950's, and the source of the injury was identified as oxidants (ozone). In an inventory begun in 1968, Miller found that sensitive ponderosa and Jeffrey pines were being selectively removed by oxidant air pollution. Mortality of 8 and 10 percent was found in two respective populations of ponderosa pine studied between 1968 and 1972. Monitoring in that period showed ozone concentrations $\geq$0.08 ppm for $\geq$1300 hours, with concentrations rarely decreasing below 0.05 ppm at night near the crest of the mountain slope (Miller, 1973).

In a subsequent interdisciplinary study (1973 through 1978), biotic and abiotic components and ecosystem processes were examined. The ecosystem components most directly affected were various tree species, the fungal micro-flora of needles, and foliose lichens on the bark of trees. Foliar injury on sensitive ponderosa and Jeffrey pine was observed when the 24-hr average ozone concentrations were 0.05 to 0.06 ppm. Injury, decline, and death of these species were associated with the major ecosystem changes observed (Miller et al., 1982).

Changes in the energy available to trees can influence biotic interactions, so that weakened trees are more susceptible to attack by predators such as bark beetles and to pathogens such as root rot fungi (Stark and Cobb, 1969). Studies show that fewer western pine beetles were required to kill weakened trees; and stressed pines became more susceptible to root rot fungi and showed a decrease in mycorrhizal rootlets and their replacement by saprophytic fungi.

Studies show accelerated rates of mortality of ponderosa and Jeffrey pine in the forest overstory, resulting from O_3 injury, root rot, and pine beetle attack. In some cases, removal by fire can change the basic structure of the forest ecosystem by causing replacement of the dominant conifers with self-perpetuating, fire-adapted, O_3-tolerant shrub and oak species, which are considered less beneficial than the former pine forest and which inhibit re-establishment of conifers.

The National Park Service (1985) has recently reported ozone-induced injury to vegetation in the Santa Monica Mountains National Recreational Area, the Sequoia and Kings Canyon National Parks, Indiana Dunes National Lakeshore, Great Smoky Mountains National Park, and the Congaree Swamp National Monument.

Extent of Impact

In Table 3, 1983 ozone concentrations for Standard Metropolitan Statistical Areas (SMSAs) having populations $\geq$ 1 million are given by geographic area, demarcated according to United States Census divisions and regions (U.S. Department of Commerce, 1982). The second-highest concentrations among daily maximum 1-hour values measured in 1983 in the 38 SMSAs having populations of at least 1 million ranged from 0.10 ppm in the Ft. Lauderdale, Florida; Philadelphia, Pennsylvania; and Seattle, Washington, areas to 0.37 ppm in the Los Angeles-Long Beach, California, area. The second-highest value among daily maximum 1-hour ozone concentrations for 35 of the 38 SMSAs in Table 3 equaled or exceeded 0.12 ppm.

A pattern of concern in assessing responses to ozone in human populations and in vegetation is the occurrence of repeated or prolonged multiday periods when the ozone concentrations in ambient air are in the range of those known to elicit responses. In addition, the number of days of respite between such multiple-day periods of high ozone is of possible consequence. Data show that repeated, consecutive-day exposures to or respites from specified concentrations are location-specific. At a site in Dallas, Texas, for example, daily maximum 1-hour concentrations were $\geq$ 0.06 ppm for 2 to 7 days in a row 37 times in a 3-year period (1979 through 1981).

A concentration of $\geq$ 0.18 ppm was recorded at that site on only 2 single days, however, and no multiple-day recurrences of that concentrations or greater were recorded over the 3-year period. At a site in Pasadena, California, daily maximum 1-hour concentrations $\geq$ 0.18 ppm recurred on 2 to 7 consecutive days 33 times in that same 3-year period (1979 through 1981) and occurred, as well, on 21 separate days. These and other data demonstrate the occurrence in some urban areas of multiple-day potential exposures to relatively high concentrations of ozone.

Few nonurban areas have been routinely monitored for ozone concentrations. Consequently, the aerometric data base for nonurban areas is considerably less substantial than for urban areas. Data are available, however, from two special-purpose networks, the National Air Pollution Background Network (NAPBN) and the Sulfate Regional Experimental network (SURE). Data on maximum 1-hour concentrations and arithmetic mean 1-hour concentrations reveal that maximum 1-hour concentrations at nonurban sites classified as rural can sometimes exceed the concentrations observed at sites classified as suburban. For example, maximum 1-hour ozone concentrations measured in 1980 at Kisatchie National Forest (NF), Louisiana; Custer NF, Montana; and Green Mt. NF, Vermont, were 0.105, 0.070, and 0.115 ppm, respectively. For four nonurban (rural) sites in the SURE study, maximum 1-hour ozone concentrations were 0.106, 0.107, 0.117, and 0.153. At the five nonurban (suburban) sites of the SURE study, maximum concentrations were 0.077, 0.099, 0.099, 0.080, and 0.118 ppm, respectively.

Ranges of concentrations and the maximum 1-hour concentrations at some of the NAPBN and SURE sites show the probable influence of ozone transported from urban areas. In one documented case, for example, a 1-hour peak ozone concentration of 0.125 ppm at a NAPBN site in Mark Twain National Forest, Missouri, was measured during passage of an air mass whose trajectory was calculated to have included Detroit, Cincinnati, and Louisville in the preceding hours.

The data corroborate the conclusion given in the 1978 criteria document (U.S. Environmental Protection Agency, 1978) regarding urban-nonurban and urban-suburban gradients; i.e., nonurban areas may sometimes sustain higher peak ozone concentrations than those found in urban areas.

Future Trends

Recent air quality data (1982-1984) indicte that 73 urban areas have recorded violations of the national ambient air quality standards. These areas stretch from coast to coast and border to border. Although there is limited data, it is reasonable to assume that ozone levels are high (in terms of the effects discussed above) in extensive rural areas as well, particularly in the eastern half of the country. Moreover, based on rough screening models, the number of urban nonattainment areas is expected to decrease slightly during the next decade and then climb again toward the turn of the century. A comprehensive ozone attainment strategy is now under development in the Agency aimed at arresting this predicted trend. However, the task will be extremely difficult and costly, inasmuch as most of the "easy" sources to control (refineries, chemical plants, automobiles, etc.) have already been regulated.

III. ACID DEPOSITION

Sources of Stress

The primary materials of concern to terrestrial and aquatic ecosystems are compounds of sulfur and nitrogen. In soil and water systems, both anthropogenically derived and naturally derived sulfur compounds are important; the percentages cannot be readily established. However, biological production of nitrogen compounds may about equal that from anthropogenic sources in many soil and water systems. For the eastern United States, anthropogenic sources account for at least 90 percent of the sulfur compounds found in air and at least 80 percent of the nitrogen compounds (ammonia and its salts, and nitrogen oxides). Table 4 lists the major sources and their emissions. Figure 1 shows the distribution of SO_2 emissions by State. Emissions of SO_2 and NO_x can be considered to be continuous.

A source close to a sensitive region will contribute relatively larger amounts of sulfur or nitrogen than will a source farther away. Prevailing weather patterns exist, at least in broad terms; on the average the wind blows more often from the Southwest to the Northeast. Hence, sources upwind will contribute relatively more to deposition in sensitive regions than sources downwind from them. Furthermore, sources with tall stacks will have a somewhat greater proportion of their emissions transported long distances. These patterns have particular importance for receptor's in the Northeast.

Sulfur enters a soil system through several pathways: mineral weathering, precipitation, dry deposition on the soil, washout of material dry deposited on other surfaces (the forest canopy, for instance), and the fall and decomposition of biological material that has taken up sulfur either from the soil or the air. Adsorption of most sulfate deposited on soils can continue as long as several decades especially in the Ultisols of the Southeast. Much of the organically-bound sulfur in soils has accumulated over the centuries. By 1950 in the eastern United States sulfur compounds in the air were already at least 80 percent anthropogenically derived; even in soils with high adsorption of sulfate, there will be a substantial excess flow of sulfur over that to be expected with only naturally derived inputs.

Sulfur enters aquatic systems through all the same pathways it enters soils; in addition, water passing through soils may account for much of the sulfur entering an aquatic system. Like the soil system, the reservior of water and sediments can also store sulfur. Because the average residence time for water is seldom longer than a decade, in most lakes only the sediments provide significant sulfur storage.

The case of nitrogen compounds is in one respect simpler, because nitrogen adsorption does not appear significant in soils. Complications arise, however, because there are two important families of nitrogen compounds, ammonia with its salts, and nitrogen oxides. Biological activity can affect either family and convert between them, and nitrogen is frequently the limiting nutrient for many ecosystems. Furthermore, the biological process of nitrogen fixation of nitrogen gas from the air can act as another source of nitrogen compounds for soil and aquatic systems. Deposition of nitrogen compounds from the atmosphere (primarily anthropogenically derived in the eastern United States) dominates biological nitrogen fixation.

Effects

Some lakes and streams have been made sufficiently acidic that their fish populations have been lost. The earliest concerns about acid deposition in Europe and in North America were about harmful effects on aquatic systems. Although numerous difficulties deter obtaining reliable historical data on aquatic chemistry, enough studies have been done at enough different locations to provide a clear scientific consensus. The pH or alkalinity declines (specifically, acid neutralizing capacity, ANC) have occurred in some surface waters over broadly distributed regions in Europe and North America; the only plausible explanation for these changes is acid deposition from anthropogenic sources.

Lakes with ANC less than zero and pH less than five are classified as acidic. The results of a recent eastern lake survey indicate that the largest estimated number of lakes with pH less than five are in the Adirondacks, Michigan's Upper Peninsula, and Florida. Other potentially sensitive areas contain few lakes with pH less than five. The largest estimated number of lakes with ANC less than zero are in the same regions. The overall estimated percentages of lakes in these regions with pH less than five are: Adirondacks, 10 percent; Michigan's Upper Peninsula, 9 percent; and Florida, 12 percent. These percentages are smaller when expressed on a lake area basis.

Acidic deposition also might be implicated in recently reported regional forest declines. Over broad areas of the eastern United States and northern Europe substantial declines in coniferous forest growth and diebacks of forest areas have been observed. The declines or dieback appeared approximately 25 years ago, a period of time when emissions of acid precursors increased substantially. A number of mechanisms have been proposed relating forest declines to acidic deposition; however, more detailed observations attempting to establish the connection between declines and deposition have provided mixed evidence. Some support but also some contrary evidence exists for each mechanism.

Extent of Impact

For acid deposition to cause adverse effects it is necessary both that the environmental system of concern be sensitive to deposition and that it actually receive substantial amounts of deposition. Except for comparatively small areas, it appears that the combination of sensitivity and high deposition is found primarily in the northeastern and southeastern United States, especially in mountainous areas.

The environmental systems of most concern are aquatic systems--lakes and streams--and forests. An aquatic system appears to be vulnerable to acid deposition if it can provide only a limited amount basic cations and if the terrestrial system within the watershed passes sulfur and/or nitrogen compounds through while adding only a limited amount of basic cations. High mountain terrain, where there are steep slopes and very little soil, passes sulfur and nitrogen compounds essentially unaltered. The same is true of areas where the predominant soil type is Spodosol*--acid soils that provide limited amounts of basic material and do not adsorb sulfate. Spodosols are the predominant soil type over much of the northeastern United States.

Other soil types in which future effects on aquatic systems may occur are Ultisols together with certain Inceptisols. These also do not provide many basic cations; however, they do adsorb sulfate, thus slowing the response of the aquatic system to increased acid deposition. These soils predominate in the Southeast, and it is quite possible that at many locations the time before response would be between one and several decades. Since deposition in the southeast probably increased one to two decades ago, these soil regions might be the locations where new adverse effects would be seen in the relatively near future.

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*Spodosol, Ultisol and Inceptisol are soil classifications, varying in several characteristics, one being natural acidity--Spodosols are the most acid of the three.

Figure 2 shows the wet deposition pH contours superimposed upon the terrain and soil regions of concern; Figure 3 shows the deposition contours superimposed upon regions where extensive areas of low surface water alkalinity are found (portions of the regions identified as < 200 ueq 1^{-1}).

Diebacks and declines have been observed in high elevation conifer forests in the Northeast; however, this may relfect more the distribution of observations than the actual distribution of impacted forests. Figure 4 shows the deposition contours and the distribution of high-elevation coniferous forests. To the extent that acidic deposition were to affect forests through changes in aluminum mobilization in soils, the most sensitive regions would be those having vulnerable trees where Spodosols predominate, with future impacts possible in Ultisol and Inceptisol regions. To the extent that acidic deposition directly affects foliage, the most sensitive regions would be found where deposition is heavy and vulnerable species of trees exist. Neither effect may prove to be important.

Future Trends

In the absence of new efforts at regulating the emissions of acid precursors, the best prediction appears to be that sulfur emissions will remain relatively constant in the next decade, while nitrogen oxide emissions will increase slightly both regionally and nationally. Total emissions of acid precursors are unlikely to change more than 10 percent. The prediction is based on continuing implementation of new source performance standards which will tend gradually to reduce emissions as new sources replace old ones, and a moderate increase in economic activity, which will tend to increase emissions.

If emissions were to remain within 10 percent of their present values, then deposition amounts also would, although there might be some regional differences as patterns of emissions change. Thus deposition would be more likely to decline slightly in the Northeast and to increase slightly in the Southeast judging from emissions trends in the recent past. Changes of 10 percent or less in average deposition are smaller than the year to year fluctuations in deposition amounts and thus would not likely produce noticeable changes in the response of either aquatic systems or forests.

The real question is whether future harm would show up as a result of the accumulation of acidifying substances at present levels of deposition. For the case of aquatic systems the most important storage mechanism appears to be sulfate adsorption in soils; this would likely be important only in the Southeast. Thus, a continuation of deposition in today's amount would not likely change by very much the numbers of Northeastern lakes or streams adversely affected, though some future change in individual lakes or streams, perhaps as a result of episodic fluctuations in deposition, could not be ruled out. In the Southeast it is possible that more lakes and streams would be adversely affected as the accumulation of sulfate made adsorption less of a barrier to the passage of sulfate into the aquatic system.

Because the mechanisms, if any, through which acid deposition might harm forests are not understood, and, in particular, forest response times are not known, it is impossible to say at present whether continued deposition would produce any adverse effects. Since forest growing times are as long or longer than the two decades or so that deposition has approximated its present values, accumulating damage would have to be considered possible.

REFERENCES

U.S. Environmental Protection Agency. (1978) Air quality criteria for ozone and other photochemical oxidants. Research Triangle Park, NC: U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office; EPA report no. EPA-600/8-78-004.

U.S. Environmental Protection Agency. (1986) Air quality criteria for ozone and other photochemical oxidants. Research Triangle Park, NC: U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office; EPA report no. EPA-600/8-84-020a.F.

U.S. Environmental Protection Agency. (1986) Acid Deposition Research Program, Office of Acid Deposition, Environmental Monitoring, and Quality Assurance. Prepared by ICAIR Life Systems, Inc; Contract Number 68-02-4193.

U.S. Environmental Protection Agency. (1985) The Acid Deposition Phenomenon and its Effects; Critical Assessment Document, Office of Acid Deposition, Environmental Monitoring and Quality Assurance. EPA Report no. EPA-600/8-85/001.

TABLE 1. FOLIAR INJURY RESPONSE OF VARIOUS PLANT SPECIES TO OZONE AND OZONE PLUS SULFUR DIOXIDE[a]

Species	Concentration[b], ppm		Exposure duration	Response	Foliar injury, %			Interaction[c] effect	Monitoring method[a]	Calibration method	Fumigation facility	Reference
	O_3	SO_2			O_3	SO_2	$SO_2 + O_3$					
Apple (Vance Delicious)	0.40	0.40	O_3-4 hr/day, 1 time SO_2-4 hr/day, 1 time	Foliar injury	24	8	26	-6	O_3-Mast meter	KI	Controlled environment chambers	Shertz et al. (1980a)
(Imperial McIntosh)					30	9	22	-17	SO_2-Not given	Permeation tubes		
(Golden Delicious)					27	19	19	-27				
Grape (Ives)	0.40	0.40	O_3-4 hr/day, 1 time SO_2-4 hr/day	Foliar injury	27	18	47	2	O_3-Mast meter SO_2-Not given	KI Permeation tubes	Controlled environment chambers	Shertz et al. (1980b)
(Delaware)					1	1	4	2				
Radish	0.15	0.15	O_3-6 hr/day, 5 days SO_2-4 hr/day, 5 days	Foliar injury	13	1	30	16	O_3 -UV Dasibi SO_2-Conductivity	Not given Not given	Exposure chambers in environmentally controlled room	Beckerson and Hofstra (1979)
Cucumber					27	9	54	18				
Soybean					18	0	0	-18				
Begonia (Schwabenland Red)	0.25	0.50	O_3-4 hr/day every 6 days, 4 times SO_2-4 hr/day every 6 days	Foliar injury	54	2	67	11	O_3-Chemiluminescence SO_2-Flame photometry	Monitor Labs Calibrator	CSTR in greenhouse	Reinert and Nelson (1980)
(Wisper 'O' Pink)					25	1	58	32				
(Fantasy)					2	0	13	11				
(Renaissance)					15	0	18	3				
(Turo)					8	0	12	4				
Pea	0.13	0.40	O_3-4 hr, 1 time SO_2-4 hr, 1 time	Foliar	0	0	32	32	O_3-Chemiluminescence SO_2-Thermo-electron (SO_2)	KI Gas-phase titration	Plexiglas chamber	Olszyk and Tibbits (1981)

[a] Where column entry is blank, information is the same as above.

[b] Concentrations of each gas were the same when given together as when given singly.

[c] The "interaction effect" is the effect from the combination of O_3 and SO_2 minus the individual effects of O_3 and SO_2

TABLE 1. GROWTH RESPONSE OF VARIOUS PLANT SPECIES TO OZONE AND OZONE PLUS SULFUR DIOXIDE

Species	Concentration[a], ppm		Exposure duration	Response	Yield, % reduction from control (negative unless otherwise noted)			Interaction[b] effect	Monitoring method	Calibration method	Fumigation facility	Reference
	O_3	SO_2			O_3	SO_2	$SO_2 + O_3$					
Radish (Cherry Belle)	0.05	0.05	8 hr/day, 5 days/wk, 5 wks	Top dry wt	10	0	10	0	O_3-Mast meter	KI	Chambers in greenhouse	Tingey et al. (1971a)
				Root dry wt	50	17	55	-12	SO_2-Conductivity	Colorimetric		
Alfalfa (Vernal)	0.05	0.05	8 hr/day, 5 days/wk 12 wk	Top dry wt	12	26	18	-20 -27	O_3-Mast meter	KI	Chambers in greenhouse	Tingey and Reinert (1975)
				Root dry wt	22	29	24		SO_2-Conductivity	Colorimetric		
Soybean (Dare)	0.05	0.05	7 hr/day, 5 days/wk 3 wk	Top fresh wt	2	+5	12	15	O_3-Mast meter	KI	Chambers in greenhouse	Tingey et al. (1973c)
				Root fresh wt	3	0	24	21	SO_2-Conductivity	Colorimetric		
Soybean (Dare)	0.10	0.10	7 hr/day, 5 days/wk, until harvest	Top fresh wt	65	+3	52	-10	O_3-Mast meter	KI	Field chambers	Heagle et al. (1974)
				Seed wt	54	4	63	5	SO_2-Flame photometry	Not given		
Tobacco (Bel-W_3)	0.05	0.05	7 hr/day, 5 days/wk, 4 wk	Leaf dry wt	1	14	30	15	O_3-Mast meter SO_2-Conductivity	KI Colorimetric	Chambers in greenhouse	Tingey and Reinert (1975)

[a] Concentrations of each gas were the same when given together as when given singly.

[b] The "interaction effect" is the effect from the combination of O_3 and SO_2 minus the individual effects of O_3 and SO_2

TABLE 1. YIELD RESPONSES OF VARIOUS PLANT SPECIES TO OZONE AND OZONE PLUS SULFUR DIOXIDE

Species	Concentration[a] ppm O_3	Concentration[a] ppm SO_2	Exposure duration	Response	Yield, % reduction from control (negative unless otherwise noted) O_3	SO_2	$SO_2 + O_3$	Inter-action[b] effect	Monitoring method	Calibration method	Fumigation facility	Reference
Tomato (Walter)	0.20	0.20	O_3-4 hr/day, 2 day/wk, 8 wk SO_2-4 hr/day, 2 day/wk, 8 wk	Largest fruit each cluster	1	2	18	15	O_3-Chemiluminescence SO_2-Flame photometry	Known source Permeation tube	Chambers in greenhouse (CSTR)[b]	Shew et al. (1982)
				Total fruit	5	4	4	-5				
Begonia (Schwabenland Red)	0.25	0.50	O_3-4 hr/day, every 6 days for 4 times, SO_2-4 hr/day every 6 days 4 for times	Flower wt	39	22	38	-23	O_3-Chemiluminescence SO_2-Flame photometry	Known source Permeation tube	Chambers in greenhouse (CSTR)	Reinert and Nelson (1980)
(Wisper 'O' Pink)	0.25	0.50		Flower wt	22	+16	28	22				
(Fantasy)	0.25	0.50		Flower wt	6	9	21	6				
(Renaissance)	0.25	0.50		Flower wt	55	43	54	-44				
(Turo)	0.25	0.50		Flower wt	+10	+11	4	25				
Snap bean (BBL 290) (BBL 274) (Astro)	0.065[b]	0.30	O_3-11 hr/day avg, 3 mo SO_2-6 hr/day, 5 day/wk, 5 wk	Green pod wt	2	16	44	26	O_3-Not given SO_2-Pulse fluorescence	Not given Permeation tube	Field chamber (open top)	Heggestad and Bennett (1981)
Tall fescue (Alta)	0.10	0.10	O_3 and SO_2 6 hr/day, once a week for 12 weeks	No. of tillers	+1	6	4	-1	O_3-UV SO_2-Pulse fluorescence	UV photometry greenhouse Permeation tube	Chambers in (1982a) (CSTR)	Flagler and Youngner (1982a)
	0.20	0.10			6	6	+12	0				
	0.30	0.10			+5	6	19	18				
	0.10	0.10		Top dry wt	+3	5	18	16				
	0.20	0.10			19	5	19	-5				
	0.30	0.10			18	5	53	30				
Alfalfa (Mesa-Sirsa)	0.05	0.05	O_3-6 hr/day, SO_2-24 hr/day, 68 days	Foliage dry 68 days	49		46	-3	O_3 Mast meter	KI	Field chamber (closed top	Neely et al. (1977)

[a]Concentrations of each gas were the same when given together as when given singly.

[b]CSTR = Continuous stirred tank reactor exposure chamber.

[c]The "interaction effect" is the effect from the combination of O_3 and SO_2 minus the individual effects of O_3 and SO_2

TABLE 2 EFFECTS OF LONG-TERM, CONTROLLED EXPOSURES ON GROWTH, YIELD AND FOLIAR INJURY IN SELECTED PLANTS[a]

Plant species	Ozone concentration, μg/m³ (ppm)	Exposure time	Plant response, % reduction from control
Lemna, duckweed	196 (0.10)	5/day, 14 days	100, flowering; 36, flowering (1 wk after exposure completed) 50, frond doubling rate
Carnation	98-177 (0.05-0.09)	24/day, 90 days	50, flowering (reduced vegetative growth)
Geranium	137-196 (0.07-0.10)	9.5/day, 90 days	50, flowering (shorter flower lasting time, reduced vegetative growth)
Petunia	98-137 (0.05-0.07)	24/day, 53 days	30, flower fresh wt
Poinsettia	196-235 (0.10-0.12)	6/day, 5 days/week, 10 weeks	39, bract size
Radish	98 (0.05)	8/day, 5 days/week, 5 weeks	54, root fresh wt 20, leaf fresh wt
	98 (0.05)	8/day, 5 days/week (mixture of O_3 and SO_2 for same periods)	63, root fresh wt 22, leaf fresh wt
Beet, garden	392 (0.20)	3/day, 38 days	50, top dry wt
Bean, cultivar Pinto	255 (0.13)	8/day, 28 days	79, top fresh wt 73, root fresh wt 70, height
Bean, cultivar Pinto	290 (0.15)	2/day, 63 days	33, plant wt; 46, pod fresh wt
	490 (0.25)	2/day, 63 days	95, plant dry wt; 99, pod fresh wt
	686 (0.35)	2/day, 63 days	97, plant dry wt; 100, pod fresh wt
Bean, cultivar Pinto	290 (0.15)	2/day, 14 days	8, leaf dry wt
	290 (0.15)	3/day, 14 days	8, leaf dry wt
	290 (0.15)	4/day, 14 days	23, leaf dry wt (data available on whole plants, roots, leaves, injury, and three levels of soil moisture stress)
	290 (0.15)	6/day, 14 days	49, leaf dry wt
	440 (0.225)	2/day, 14 days	44, leaf dry wt
Bean, cultivar Pinto	440 (0.225)	4/day, 14 days	68, leaf dry wt (data available on whole plants, roots, leaves, injury, and three levels of soil moisture stress)
	588 (0.30)	1/day, 14 days	40, leaf dry wt

TABLE 2. (cont'd). EFFECTS OF LONG-TERM, CONTROLLED OZONE EXPOSURES ON GROWTH, YIELD AND FOLIAR INJURY IN SELECTED PLANTS[a]

Plant species	Ozone concentration, μg/m³ (ppm)	Exposure time	Plant response, % reduction from control
	588 (0.30)	3/day, 14 days	76, leaf dry wt
Tomato	392 (0.20)	2.5/day, 3 days/week 14 weeks	1, yield; 32 top dry wt; 11, root dry wt
	686 (0.35)	2.5/day, 3 days/week, 14 weeks	45, yield; 72, top dry wt; 59, root dry wt
Corn, sweet, cultivar Golden Jubilee	392 (0.20)	3/day, 3 days/week till harvest	13, kernel dry wt; 20, top dry wt; 24, root dry wt
	686 (0.35)	3/day, 3 days/week till harvest	20, kernel dry wt; 48, top dry wt; 54, root dry wt
Wheat, cultivar Arthur 71	392 (0.20)	4/day, 7 days (anthesis)	30, yield
Soybean	98 (0.05)	8/day, 5 days/week 3 weeks	13, foliar injury
		8/day, 5 days/week (mixture of O_3 and SO_2 for same periods)	16, foliar injury 20, root dry wt
Soybean	196 (0.10)	8/day, 5 days/week 3 weeks	21, top dry wt 9, root dry wt
Alfalfa	196 (0.10) 290 (0.15) 390 (0.20)	2/day, 21 days 2/day, 21 days 2 day, 21 days	16, top dry wt 26, top dry wt 39, top dry wt
Grass brome	290-647 (0.15-0.33)(varied)	4/day, 5 days/week growing season	83, biomass
Alfalfa[b]	196 (0.10)	6/day, 70 days	4, top dry wt, harvest 1 20, top dry wt, harvest 2 50, top dry wt, harvest 3
Alfalfa[b]	98 (0.05)	7/day, 68 days	30, top dry wt, harvest 1 50, top dry wt, harvest 2
Alfalfa	98 (0.05)	8/day, 5 days/week 12 weeks	18, top dry wt
Pine, eastern white	196 (0.10)	4/day, 5 days/week 4 weeks (mixture of O_3 and SO_2 for same periods)	3, needle mottle (over 2-3 days of exposure) 16, needle mottle

TABLE 2. (cont'd). EFFECTS OF LONG-TERM, CONTROLLED OZONE EXPOSURES ON GROWTH, YIELD AND FOLIAR INJURY IN SELECTED PLANTS[a]

Plant species	Ozone concentration, μg/m³ (ppm)	Exposure time	Plant response, % reduction from control
Pine, ponderosa	290 (0.15)	9/day, 10 days	4, photosynthesis
	290 (0.15)	9/day, 20 days	25, photosynthesis
Pine, ponderosa	290 (0.15)	9/day, 30 days	25, photosynthesis
	290 (0.15)	9/day, 60 days	34, photosynthesis
	588 (0.30)	9/day, 10 days	12, photosynthesis
	588 (0.30)	9/day, 20 days	50, photosynthesis
	588 (0.30)	9/day, 30 days	72, photosynthesis
	880-588 (0.30)	9/day, 30 days	85, photosynthesis
Poplar, yellow	588-880 (0.45)	9/day, 30 days 13 weeks	82, leaf drop; 0, height
Maple, silver	588 (0.30)	8/day, 5 days/week 13 weeks	50, leaf drop; 78, height
Ash, white	588 (0.30)	8/day, 5 days/week 13 weeks	66, leaf drop; 0, height
Sycamore	588 (0.30)	8/day, 5 days/week 13 weeks	0, leaf drop; 22, height
Maple, sugar	588 (0.30)	8/day, 5 days/week 13 weeks	28, leaf drop; 64, height
Corn, sweet, cultivar Golden Midget[c]	98 (0.05)	6/day, 64 days	9, kernel dry wt; 14, injury (12, avg. 4 yield responses)
	196 (0.10)	6/day, 64 days	45, 25, 35 for same responses
Pine, ponderosa[b]	196 (0.10)	6/day, 126 days	12, root length 21, stem dry wt; 26, root dry wt
Pine, western white[b]	196 (0.10)	6/day, 126 days	13, foliage dry wt 9, stem dry wt
Soybean, cultivar Dare[b]	98 (0.05)	6/day, 133 days	3, seed yield; 22, plant fresh wt; 19, injury, defoliation, no reduction in growth or yield
	196 (0.10)	6/day, 133 days	55, 65, 37 for same responses
Poplar, hybrid	290 (0.15)	8/day, 5 days/week 6 weeks	50, shoot dry wt; 56, leaf dry wt; ; 47, root dry wt

[a] Modified from National Research Council (1977); cited in U.S. Environmental Protection Agency (1978).

[b] Studies conducted under field conditions, except that plants were enclosed to ensure controlled pollutant doses. Plants grown under conditions making them more sensitive.

TABLE 3. SECOND-HIGHEST OZONE CONCENTRATIONS AMONG DAILY MAXIMUM 1-hr VALUES IN 1983 IN STANDARD METROPOLITAN STATISTICAL AREAS WITH POPULATIONS ≥ 1 MILLION, GIVEN BY CENSUS DIVISIONS AND REGIONS[a]

Division and region	SMSA	SMSA population, millions	Second-highest 1983 O_3 concn., ppm
Northeast			
New England	Boston, MA	>2	0.18
Middle Atlantic	Buffalo, NY	1 to <2	0.12
	Nassau-Suffolk, NY	>2	0.17
	Newark, NJ	1 to <2	0.25
	New York, NY/NJ	>2	0.19
	Philadelphia, PA/NJ	>2	0.10
	Pittsburgh, PA	>2	0.14
South			
South Atlantic	Atlanta, GA	>2	0.17
	Baltimore, MD	>2	0.19
	Ft. Lauderdale-Hollywood, FL	1 to <2	0.10
	Miami, FL	1 to <2	0.12
	Tampa-St. Petersburg, FL	1 to <2	0.14
	Washington, DC/MD/VA	>2	0.17
South			
West South Central	Dallas-Ft. Worth, TX	>2	0.16
	Houston, TX	>2	0.28
	New Orleans, LA	1 to <2	0.12
	San Antonio, TX	1 to <2	0.12
North Central			
East North Central	Chicago, IL	>2	0.17
	Detroit, MI	>2	0.17
	Cleveland, OH	1 to <2	0.15
	Cincinnati, OH/KY/IN	1 to <2	0.15
	Milwaukee, WI	1 to <2	0.18
	Indianapolis, IN	1 to <2	0.14
	Columbus, OH	1 to <2	0.12
West North Central	St. Louis, MO/IL	>2	0.18
	Minneapolis-St. Paul, MN/WI	>2	0.13
	Kansas City, MO/KS	1 to <2	0.13

TABLE 3. (cont'd). SECOND-HIGHEST OZONE CONCENTRATIONS AMONG DAILY MAXIMUM 1-hr VALUES IN 1983 IN STANDARD METROPOLITAN STATISTICAL AREAS WITH ≥ 1 MILLION, GIVEN BY CENSUS DIVISIONS AND REGIONS[a]

Division and region	SMSA	SMSA population, millions	Second-highest 1983 O_3 concn., ppm
West			
Mountain	Denver-Boulder, CO	1 to <2	0.14
	Phoenix, AZ	1 to <2	0.16
Pacific	Los Angeles-Long Beach, CA	>2	0.37
	San Francisco-Oakland, CA	>2	0.17
	Anaheim-Santa Ana-Garden Grove, CA	1 to <2	0.28
	San Diego, CA	1 to <2	0.20
	Seattle-Everett, WA	1 to <2	0.10
	Riverside-San Bernardino-Ontario, CA	1 to <2	0.34
	San Jose, CA	1 to <2	0.16
	Portland, OR/WA	1 to <2	0.12
	Sacramento, CA	1 to <2	0.15

[a] Standard Metropolitan Statistical Areas and geographic divisions and regions as defined by Statistical Abstract of the United States (U.S. Department of Commerce, 1982).

TABLE 4. NATIONAL U.S. CURRENT AND PROJECTED SO_2 AND NO_x EMISSIONS (Tg yr^{-1})[a]

	Current 1980		Projected 1990		Projected 2000	
Source category	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
1. Electric utilities	15.0	5.6	15.9	7.2	16.2	8.7
2. Industrial boilers and process heaters	2.4	3.5	3.4	3.0	6.5	4.0
3. Nonferrous smelters	1.4		0.5		0.5	
4. Residential/commercial	0.8	0.7	1.0	0.7	0.9	0.6
5. Other industrial processes	2.9	0.7	1.2	0.8	1.5	1.1
6. Transportation	0.8	8.5	0.8	7.8	1.0	9.7
TOTALS	24.1	19.0	22.8	19.5	26.6	24.1

[a] Summarized from U.S./Canada Work Group 3B Draft Report (1982).

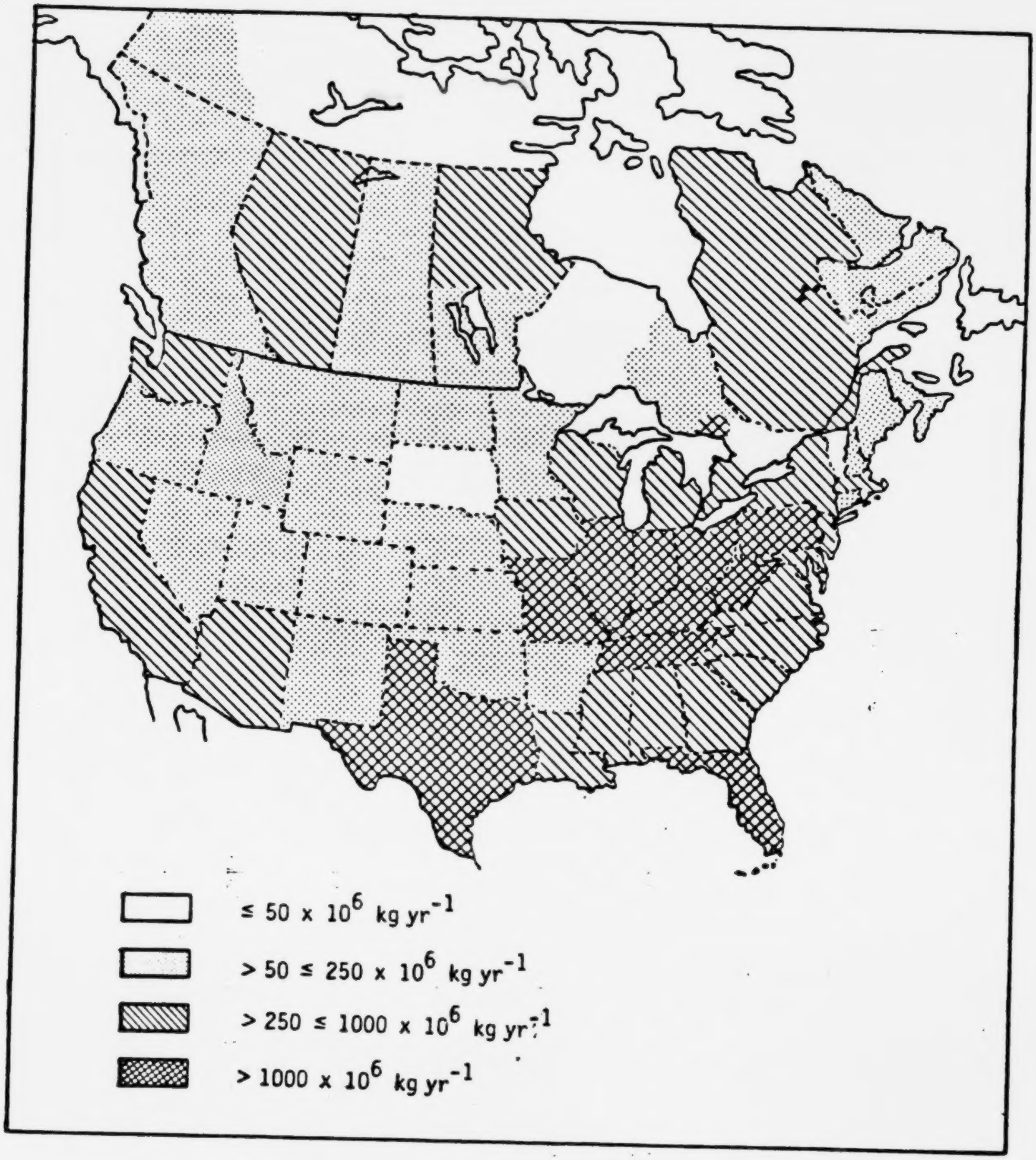
$\leq 50 \times 10^6$ kg yr^{-1}
$> 50 \leq 250 \times 10^6$ kg yr^{-1}
$> 250 \leq 1000 \times 10^6$ kg yr^{-1}
$> 1000 \times 10^6$ kg yr^{-1}

Figure 1. Annual 1980 emissions of SO_2 by state. Data are from Toothman et al. (1984)

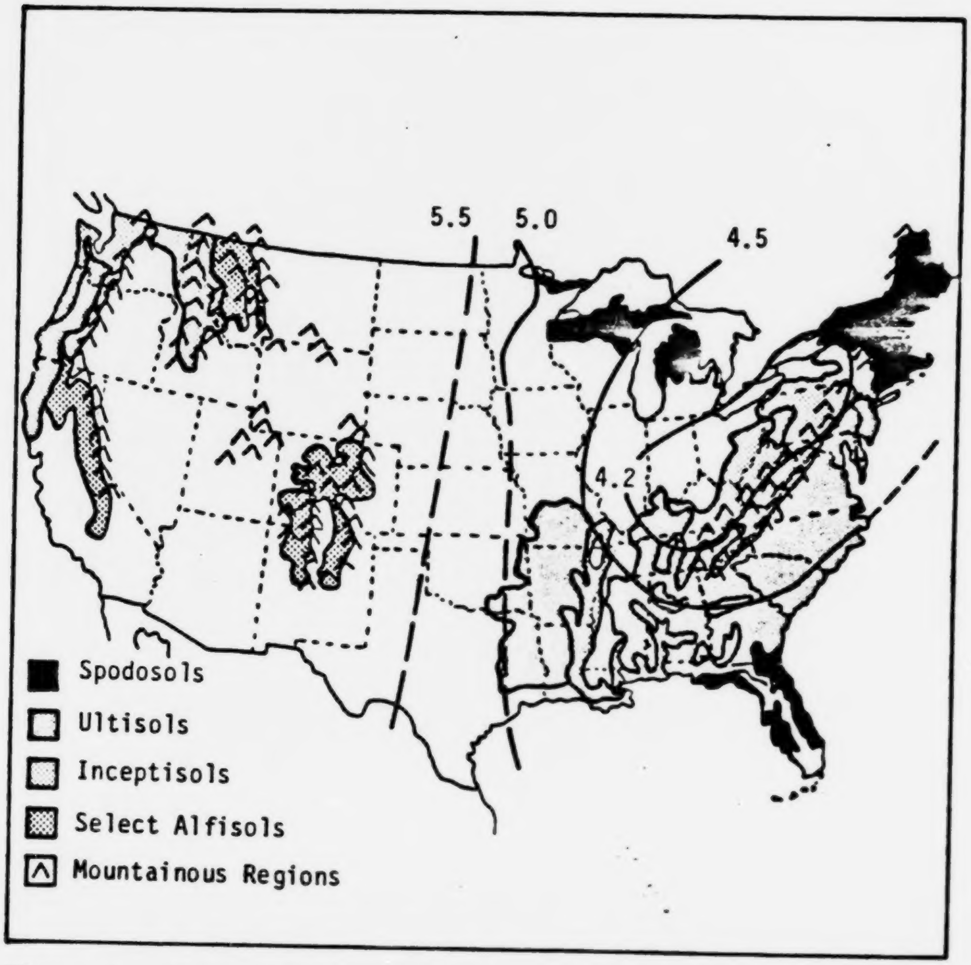
5.5
5.0
4.5
4.2
Spodosols
Ultisols
Inceptisols
Select Alfisols
Mountainous Regions

Figure 2. pH contour lines and soil regions of concern in the United States.

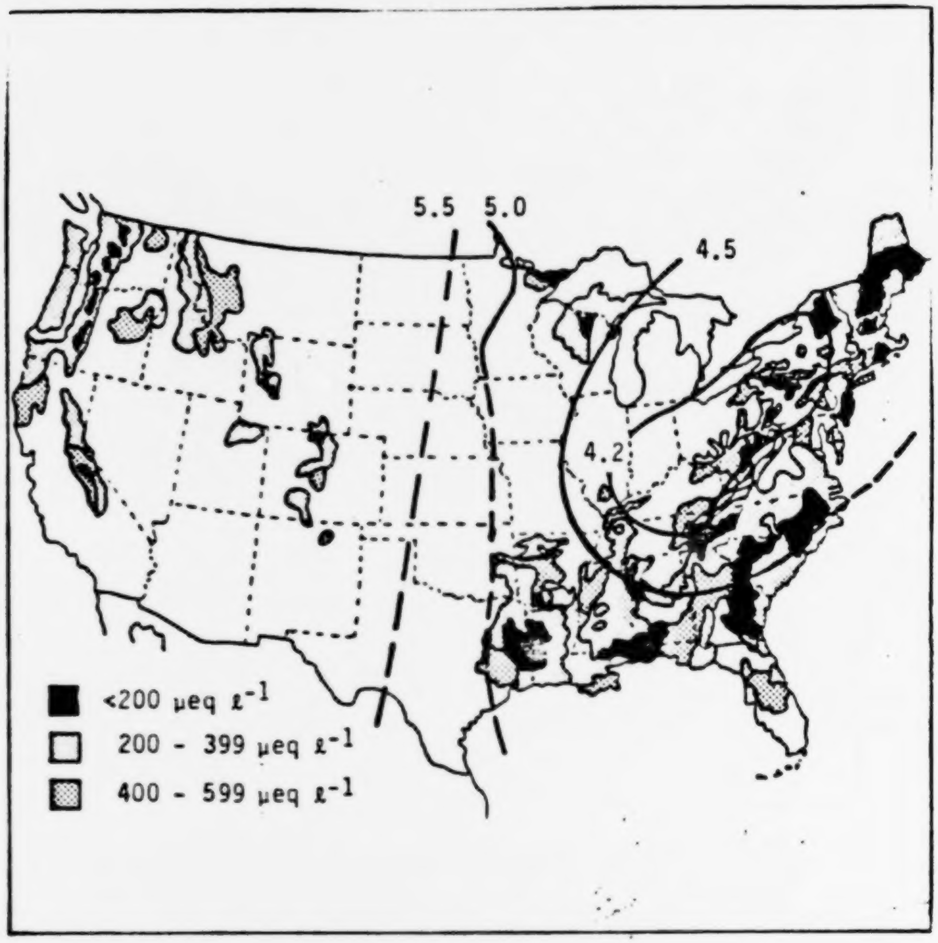
5.5
5.0
4.5
4.2
■ <200 μeq ℓ⁻¹
☐ 200 - 399 μeq ℓ⁻¹
▨ 400 - 599 μeq ℓ⁻¹

Figure 3. pH contour lines and low alkalinity surface waters in the United States.

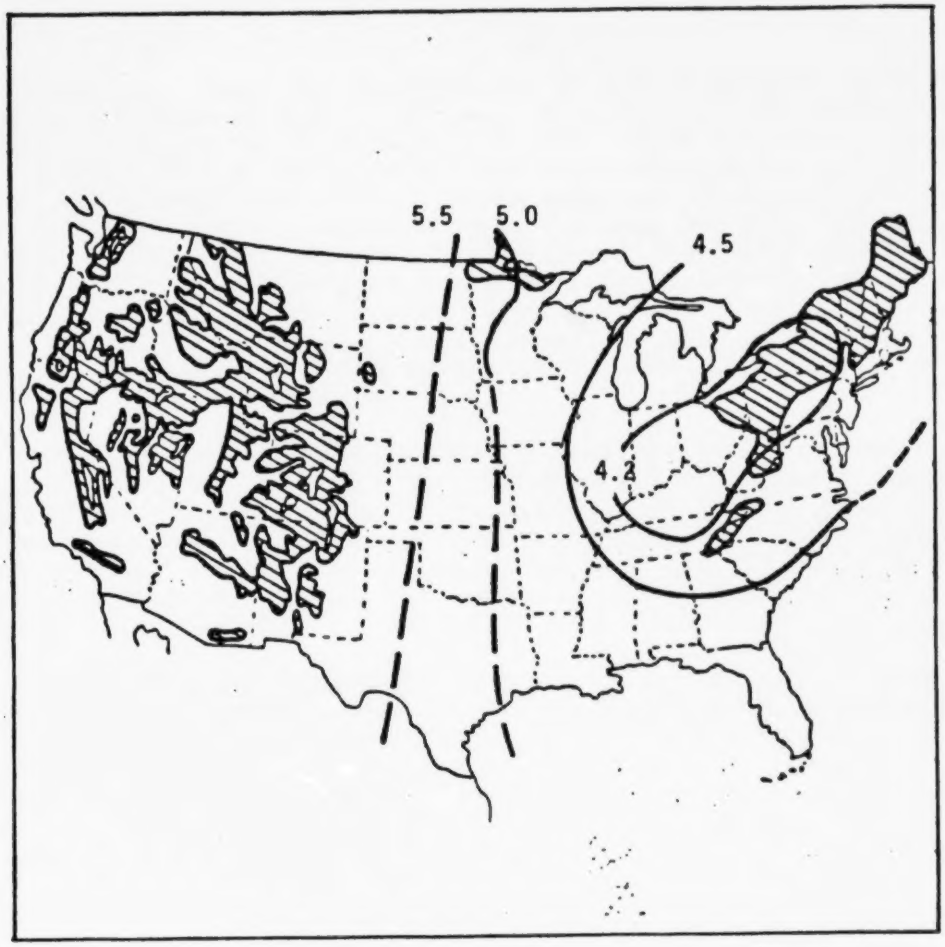

Figure 4. pH contour lines and high-elevation forests in the United States.

DRAFT #2
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TOXIC AIR POLLUTANTS:
A PRELIMINARY ASSESSMENT OF ECOLOGICAL RISKS

I. OVERVIEW

Definition. Toxic air pollutants can be defined generally as virtually any substance released into the air media that may pose unreasonable risk to human health and the environment. By such a broad definition, toxic air pollutants include air quality criteria pollutants (i.e., sulfer oxides, ozone, particulate matter, carbon monoxide, nitrogem oxides, and lead) that are separately regulated under the Clean Air Act. For this analysis, criteria air pollutants from mobile and stationary sources, acid precipitation, are excluded from this analysis, because they are addressed as a separate environmental problem area[1]. Additionally, indoor air pollution, although a major concern in terms of human health risks, is not addressed in this paper because it does not appear to pose significant risks to ecosystems.

Background. A significant problem in assessing ecologcal risks is that the air toxics problem has been defined within the Agency in terms of potential human health problems[2]. The Congress, EPA and the public have focused almost exclusively on human health concerns, as evidenced by the increased recent attention to accidental releases[3] and indoor air quality[4]. Ecological effects are usually not considered or only given perfunctory mention.

The diversity and large number of toxic air pollutants, together with a lack of information and understanding of sources, ecosystem exposure patterns and ecological responses, preclude a reliable assessment of the nature and magnitude of the ecological risks. This paper presents an overview of available information that relates toxic air pollutants to ecological risks, but the great scientific uncertainties must be emphasized. The findings should be considered with caution, because our understanding of this issue will certainly change as available information grows.

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[1] Note: There is an overlap between criteria pollutants and toxic air pollutants. For example, control programs designed to reduce criteria pollutant emissions probably achieve considerable reduction is toxic air pollutants. Also, some toxic air pollutants contribute to criteria pollutant loadings (e.g., VOCs that are ozone precursors).

[2] EPA Air Toxics Strategic Planning Initiative: Problem Assessment and Goal Options Summary, July 1986; June 11, 1985 Statement on Air Toxics by Lee Thomas before the House Committee on Energy and Commerce, Subcommittee on Health and the Environment; EPA Air Toxics Strategy Document.

[3] For example, Title III of the Superfund Amendments and Reauthorization Act (SARA) gives EPA authority relating to emergency planning, emergency notification, community right-to-know reporting of chemicals, and emission inventory.

[4] For example, SARA authorizes a research program on radon gas and indoor air quality that will include characterization of sources, human health effects, and control technology.

II. DESCRIPTION OF SOURCES, RELEASES, CONTROLS AND EXPOSURES

The diversity and complexity of toxic air pollutant sources and releases is apparent from the the following categorization scheme:

Total Toxic Air Pollutant Emisions				
Conventional Releases		Short-Term Releases		
Routine Releases			Accidental Releases	
Process Emissions	Fugitive Emissions	Intermittent (Expected, Limited, Scheduled) o Startup o Shutdown o Maintenance	Intermittent (Expected, Limited, Not Scheduled) o Transient o Upset	Catastrophic (Unexpected Major Failure, Not Scheduled) o Processes or Controls Fail o Uncontrollable* o Controllable**

* e.g., Explosion of a storage tank
** e.g., Tank ruptures and released toxicants are torched (burned off)

Routine releases are defined as those emissions to ambient air that occur as part of the usual or expected operations of human activities, such as the normal operation of an industrial process. Some of the most pervasive sources of routine releases are stationary and mobile combustion sources found throughout the country, but are concentrated in urban areas. Accidental releases are those discharges that come from unplanned and unexpected discharges to ambient air, such as a storage tank rupture, process upset, or transportation accident.

Accidental releases tend to cause acute exposures. Routine releases may involve both acute and chronic exposures, depending on the quantity and duration of the material released and its toxicity.

Sources and Releases. The sources of toxic air pollutants are widely varied and include traditional air pollutant sources such as emissions from chemical plants, motor vehicles and metallurgical processes, as well as nontraditional sources such as sewage treatment plants. A detailed description of total toxic air pollutant emissions is not is not available. Further, the existing lists of toxic air pollutants are based on human health concerns and, although a large number of these compounds may also pose ecological risks, a list prepared for ecosystem protection would be somewhat different.

• In the absence of a list of toxic air pollutant sources, some examples of kinds of sources must suffice for source characterization:

- Petroleum handling, including over one million underground storage tanks (UST) that store petroleum, and 50,000 USTs that store chemicals — unknown quantity of VOCs released.
- 165,000 industrial boilers and over one million furnaces and boilers that heat buildings — 500 million gallons of used oil is recycled as fuel each year; used oil typically contains elevated levels of toxic metals such as arsenic, cadmium, and chromium, and organics such as BaP and PCBs, which are released to the air.
- 15,000 drycleaners
- 50,000 vapor degreasers that use solvents
- 175,000 commercial pesticide appliers and about one million private certified pesticide applicators (farmers)
- Wastewater treatment — 15,000 municipal and 20,000 industrial
- Superfund sites — 109 sites have been placed on the NPL due to high air sources (43 for particulate, heavy metal, or radium releases; and 67 for VOC emissions).
- Municipal landfills -- speculation that emissions may be high in some cases due to decomposing plastics, discarded solvents, and mobilization of VOCs to the atmosphere by methane gas.
- Municipal waste incinerators — preliminary estimates of high emissions of metals and organic compounds at poorly run facilities.
- Drinking water treatment plants — aeration is used to remove VOCs from water.
- Coal-fired electric power plants — estimated annual release of polycyclic aromatic hydrocarbons (PAH's) of 46,000 metric tons.
- RCRA treatment storage and disposal facilities that handle hazardous wastes — the emission sources for VOCs and particulate matter are numerous, including tanks, impoundments, waste piles, landfills, land treatment operations, equipment leaks, spills, drum storage, process vents, etc. These sources emit an estimated 3 million metric tons of VOCs annually.

In summary, a wide variety of toxic air pollutant sources may contribute to ecological risk. These include, but are not limited to: road vehicles; combustion of coal and oil, woodstoves; metallurgical industries; chemical production and manufacturing; gasoline marketing; solvent useage, and waste oil disposal. The relative importance of each is not known. Both point sources (major industrial sources) and area sources (smaller sources that may be wide spread accross a given area, such as solvent useage, motor vehicles, woodstoves) are likely contributors.

Stress Agents. The principal stress agents for ecological effects have not been identified. An EPA study of human cancer risks from air toxics[5] concluded that the following pollutants may be important contributors to aggregrate cancer incidence from air toxics: metals, asbestos, products of incomplete combustion[6], formaldehyde, benzene, ethylene oxide, gasoline vapors, and chlorinated organic compounds. Persistent compounds such as metals, PCBs and TCDD may be special importance ecologically because of foodchain effects.

Not surprisingly, trying to crosswalk specific stress agents and sources is extrardinarily complex. The source breakdown for several pollutants is provided below as an illustration:

Pollutant	Sources
Arsenic	Combustion sources such as waste oil burning, coal-fired utility boilers, wood smoke, smelters, glass manufacturing
Benzene	Road vehicles, gasoline marketing, pertoleum refining
Chloroform	Solvent usage, water treatment
Chromium	Waste oil burning, steel manufacturing, refractory manufacturing, metals manufacturing, combustion
PICs	Burning of wood and coal in small combustion units, coke operations, internal combustion engine

In terms of the "stress agents" identified by the Cornell Ecosystem Research Center, toxic air pollutants were identified as "air deposition of toxics." The Cornell panel of of experts defined this category to include aerial transport of metals and VOCs, such as PAHs and PCBs, and felt that is particularly important near urban areas due to automobile exhaust, fossil fuel combustion, and other urban sources. However, the Cornell panel may not have been aware of the full magnitude and nature of sources of toxic air pollutants.

Ecosystem Exposure. Ecosystem exposure to toxic air pollutants range from catastrophic industrial accidents (e.g., Union Carbide in Bhopal, India) to the more routine release of chemicals into the atmosphere as part of the normal operation of countless human activities. Accidental releases have emerged as a major issue in terms of protecting human health, but has not been analysed in terms of ecological risks. In fact, a recent EPA report[7] indicates that in over 90% of the accidental releases accidents reported in the United States between 1981 and 1985, the ecological consequences are listed as unknown. There are some factors that decrease the importance of chemical accident, from an ecotoxicological viewpoint (e.g., many accidents are in-plant occurences, and unless very large will not reach ecosystems). However, large releases and transportation accidents may result in greater ecosystem exposure

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[5] EPA. The Air Toxic Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants (called the "Six Month Study" because of its original intended duration), May 1986. EPA 450/1-85-001. This study is probably the most comprehensive attempt to date to assemble and analyse available data on air toxics, and was used extensively to prepare this paper.

[6] "Products of incomplete combustion" (PICs) refers to a large and ill-defined group of compounds, probably consisting primarily of polynuclear organics.

Routine releases to ecosystems has emerged as potentially significant at some locations. For example, atmospheric loading of toxic pollutants to the Great Lakes appears to be a major pathway, but the details are unknown. Exposures to point sources are most easily identified (e.g., downwind from a smelter), but the current state of our understanding is insufficient to adequately predict overall ecosystem exposures to Toxic air pollutants.

Ambient air quality and atmospheric deposition information is scarce, and is generally biased toward urban areas, but high geographic variability of toxic air pollutants is likely. Concentrations will be highest adjecent to sources, which generally means in and near urbanized areas. However, the transport of air toxics for long distances does occur -- emissions disperse rapidly downwind to affect areas not in the immediate vicinity of the source.

Overall, the geographic scale of air toxic exposure on ecosystems is not known because of the complexity of sources and pollutants, incomplete understanding of transport processes, and the paucity of monitoring data from natural ecosystems. Inputs to ecosytems that are remote from urban sources do occur, but too little is known to make generalizations.

A further complication is atmospheric transformation of toxic precursors during transport. EPA has done a preliminary assessment[8] of chemical reactions (e.g., photooxidation) in the atmosphere that can form toxic compounds or increase the potency of emitted pollutants (ozone is the prime example of this phenomenon), but existing knowledge and exposure models cannot account for toxic compounds that may be formed or destroyed in the atmposhere.

Impacts. Ecological impacts are possible for all ecosystem types from toxic air pollutants. A sizable body of scientific literature exists on air pollution damage to terrestrial vegetation, due largely to economic concerns about losses of agricultural crops and forests, and so forth. Emphasis has been on gaseous pollutants such as photochemical oxidants (e.g., ozone, nitrogen oxides, etc.) and sulfer dioxide. Atmospheric inputs to lakes have been documented, and impacts can be expected. However, a lack of information on both field exposures and toxicological effects preclude a good understanding and quantification of ecological impacts for any ecosystem types.

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[7] EPA 560/5-85-029

[8] Production of Hazardous Pollutants through Atmospheric Transformations. EPA office of REsearch and Development. June, 1984.

The biological impacts of toxic air pollutants have been studied in some detail through laboratory bioassays.[9] Although it is not possible to extrapolate thse laboratory results to the field effects, it appears that the polynuclear aromatic hydrocarbons (PAHs), nitro compounds, and halogenated compounds are potentially harmful groups. Persistent compounds such as metals, accumulate in an ecosystem may also be considered as a potentially harmful group.

The difficulty of assessing and predicting impacts from toxic air pollutants is illustrated in the dieback of german forests. Over recent years, symptoms of a new kind of damage, which includes premature tree defoliation leading to death, has appeared in a number of tree species in West Germany. The problem began in the 1970's when it was restucted to high altitudes and older trees and became more serious after 1976. It is believed that some kind of atmospheric pollution is involved. Initially, it was argued that accumulated effects of increased acidity of precipitation altered soil chemistry and damaged the trees cost systems. More recently, many doubts have been expressed about this hypothesis and ozone has been proposed as the responsible stress agent. However, scientific opinion is increasingly moving toward the view that there is no single, simple cause. The ecosystem-level effect may result from complex interactions between more than one toxic air pollutant and other environmental stresses.

Controls. Toxic compounds are emitted into the atmosphere from many sources that are controlled for CAA criteria pollutants. Metals and polynuclear compounds usually are emitted as particulate matter and most of the VOCs as ozone precursors. As such, they are regulated indirectly under the CAA through State Implementation Plans (SIPs), New Source Performance Standards (NSPS), and Title II for motor vehicles. Also, there are economic reasons for private-sector control of emission for some volatile compounds, such as solvents.

Several EPA studies[10,11] have evaluated the effects of these indirect controls on toxic air pollutants and made the following conclusions. Control of metals from point sources is generally high, ranging from 80-98%. For point-source emissions of organics, percentage controls range from 30-90%. To examine area sources and motor vehicles, air quality trends rather than control regulations have been evaluated. Generally, heavy-metal reductions of 30-70% have been observed since the 1960s. In addition, SIPs and NSPS are credited with reducing emissions of 15 chemicals from the the chemical industry by 10-80%, and 8 solvents by 30% nationwide. Motor vehicle controls now remove up to 90% of some potentially toxic compounds from exhaust gases.

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[9] Graedel, T.E., D.T. Hawkins and L.D. Claxton. 1986 Handbook of Atmospheric Compounds; Sources, occurrence, and Bioassay. Acodemic Press.

[10] EPA. Characterization of Available Nationwide Air Toxics Emissions Data. Unpublished report by Tom Lahre. June, 1984.

[11] PA. Estimation of Cancer Incidence Cases for Selected Toxic Air Pollutants Using Ambient Air Pollution Data, 1970 vs. 1980. Unpublished report by W. F. Hunt et al. April, 1985.

Even from these cursory analyses, it is apparent that indirect controls can be very significant in reducing emissions of toxic air pollutants. At this time, controls for criteria pollutants for exceed the impact of Section 112 regulations. Finally, since sources are already being controlled by criteria pollutant programs, the remaining emissions will probably be more difficult to control.

Information Availability and Quality. Major weaknesses and gaps characterize the base of information on toxic air pollutants. The few air toxics emission inventories that are available generally show inconsistencies and anomolies, the air quality data that exists is inadequate to develop ecosystem exposure estimates, and few compounds have been tested for ecotoxicological effects. The data limitations preclude performing any type of comprehensive assessment of ecological risks.

Figure 1. Proposed Ranking of Ecological Risks from Toxic Air Pollutants

Ecosystems		Intensity of Ecological Effects[12]	Reversibility of Impact[13]	Exposure[14]	Total Ecological Risk
Freshwater	Buffered lakes	L	H	M	M
	Unbuffered lakes	L	H	M	M
	Buffered streams	L	H	M	M
	Unbuffered streams	L	H	M	M
Marine and estuarine	Coastal	?	?	M	?
	Open ocean	?	?	L	?
	Estuaries	?	?	H	?
Terrestrial	Coniferous forest	?	?	M	?
	Deciduous forest	?	?	M	?
	Grassland	?	?	M	?
	Desert/Semi-arid	?	?	M	?
	Alpine/Tundra	?	?	L	?
Wetland	Freshwater - isolated	-		M	-
	Freshwater - flowing	-		M	-
	Saltwater	-		M	-

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[12] The significance of ecological effects of toxic air pollutants that reach a particular ecosystem type (? = uncerain because of insufficient ecological understanding).

[13] The time required for ecosystem recovery after an impact (L = 1 year; M = 10 years; H = 100 or more years)

[14] At a national scale, the expected exposure of different ecosystems to toxic air pollutants

Problem #6 Radioactivity - Other Than Radon

Introduction

The activities of man have increased exposure of the ecosystem to radiation in two ways. The first is by alteration of the distribution of naturally occurring radioactive material. Thus, activities such as mining, industrial processing of raw materials, and use of contaminated products can uncover and concentrate previously sequestered radioactivity. The second is through applications of nuclear technology which produce radioactive material. Thus, nuclear reactors and particle accelerators can increase the abundance of radioisotopes in the ecosystem or create radioisotopes which did not previously exist.

I. Sources, Releases, and Responses

The sources of increased exposure within the environment are widespread although some types of activity may be localized to certain areas. For example, nuclear reactors are located in nearly every state while uranium mining is confined primarily to the west. The impact of these sources may also be widespread due to releases to the atmosphere or to bodies of water. Because much of the technology is of recent origin, the overall impact is difficult to quantify due both to the relatively small amounts of material and to lack of closure of the technological cycle.

While radiation is known to be carcinogenic, mutagenic, and teratogenic, much of the data obtained is from acute exposures at high radiation levels. The effects of low level, long term exposures are not well known. In addition, most of the information obtained has been oriented toward human health effects with less emphasis placed on other aspects of the ecosystem.

II. Sources

Naturally Occurring Radioactivity

Any description of the sources of radioactivity should be prefaced with the observation that radioactive material is ubiquitous in the environment. Naturally occurring isotopes such as hydrogen-3, carbon-14, and potassium-40, have been an integral part of the ecology of the planet since its formation. There are also four primordial radioactive series. The term series connotes a chain of radioisotopes which sequentially decay until a non-radioactive isotope is reached. For example, the uranium series begins with uranium-238 which decays into thorium-234 which decays into protactinium-234. Each decay is accompanied by the emission of radioactivity and there are about thirteen decays in the chain, ending with the stable (non-radioactive) isotope lead-206. Each series is characterized by a radionuclide with long half-life (the time required for one half of the initial isotope to undergo decay), in the millions to billions of years. The most abundant is the thorium series (thorium-232, 14 billion years) followed closely by the uranium series (uranium-238, 4.5 billion years). The actinium series (uranium-235, 0.7 billion years) is much less abundant in nature and the neptunium series (neptunicum-237, 2.1 million years) did not exist in recent times until recreated by modern nuclear technology. Other radioisotopes, e.g., hydrogen-3 and carbon-14, which occur in nature are also produced in nuclear applications.

Anthropogenic Effects on Environmental Radioactivity

As noted, anthopogenically induced changes in the radiation environment may be divided into those resulting from alteration in the distribution of naturally occurring radioactivity and those resulting from applications of nuclear technology. The first category would include mining, milling, and other industrial processes. The second category would include nuclear reactors, including post-irradiation operations in the nuclear fuel cycle, and particle accelerators. A discussion of each category is given below and major sources in each summarized in Table 1.

In the first category, increased exposure of the ecosystem is due primarily to the collection or concentration of ores containing radioactive materials. A prime example is the mining and processing of uranium for use in the nuclear fuel cycle. The mining process can expose and concentrate radioactive materials and release it into the environment via wastewater streams and the release of radioactive gases, notably radon, whose decay products are also radioactive. The next step in the cycle is milling of the ore. The uranium is removed and the residue, including radium, placed in tailings piles. The refined uranium is then sent to a diffusion plant where some of it is enriched in the fissionable uranium-235 isotope. The residual uranium, termed depleted, may be stored or used for other purposes. The enriched uranium is sent to a fabrication plant to be made into fuel rods for nuclear reactors. During each phase of the processing, there is a potential for release of radioactivity into the environment.

Due to the ubiquitous nature of the primordial series, other industrial processes also contribute to the redistribution of radioactivity in the environment. Thus, any mining operation may transfer radioactive materials to the surface via mine spoils or water discharges. Phosphate ores may contain

Table 1

Summary of Dose Data from All Sources

SOURCE	EXTERNAL		INTERNAL	
	Individual dose (mrem/y)	Population dose (person-rem/y)	Individual dose (mrem/y)	Population dose (person-rem/y)
Ambient Ionizing Radiation	-	$9.7x10^6$	-	-
Cosmic radiation	40.9-45	$9.7x10^6$	-	-
Ionizing component	28-35.3	$9.2x10^6$	-	-
Neutron component	0.33-6.8	$4.9x10^5$	-	-
Worldwide radioactivity				
Tritium	-	-	0.04	$9.2x10^3$
Carbon-14	-	-	1.0	-
Krypton-85	$4x10^{-4}$	80	-	-
Terrestrial radiation	30-95	-	18-25	-
Potassium-40	17	-	16-19	-
Tritium	-	-	$4x10^{-3}$	-
Carbon-14	-	-	1.0	-
Rubidium-87	-	-	0.6	-
Polonium-210	[a]13	-	2-3	-
Radon-222	[b]25	-	3.0	-
Technologically Enhanced Natural Radiation	-	-	-	$2.73x10^6$
Ore mining and milling	-	-	-	-
Uranium mill tailings	-	-	[c]140-14000	[d]2.5-70000
Phosphate minining and processing	-	-	-	-
Thorium mining and milling	-	-	-	-
Radon in potable water supplies	-	-	-	-
Radon in natural gas	-	-	[e]54	$2.73x10^6$
Radon in liquified petroleum gas	-	-	0.9-4.0	30000
Radon in mines	-	-	-	-
Radon daughter exposure in natural caves	-	-	-	-
Radon and geothermal energy production	-	-	-	-
Radioactivity in construction material	-	-	-	-
	Individual dose (mrem/y)	Population dose (person-rem/y)	Individual dose (mrem/y)	Population dose (person-rem/y)
Medical Radiation				
X radiation	[r]20	-	-	-
Radiopharmaceuticals	-	-	-	[s]$3.3x10^6$
Occupational and Industrial Radiation				
BWR	[t]1230	-	-	-
PWR	[t]1080	-	-	-
All occupations	[u]0.80	-	-	-
Consumer Products	-	- 6100	-	-
TV	[v]0.025-0.043	-	-	-
Timepieces	-	6100	-	-
	Individual Exposure (uW/cm^2)			
Nonionizing Electromagnetic Radiation				
Broadcast towers and airport radars	10			
All sources	0.1-1			

Table 1 Cont'd

Summary of Dose Data from All Sources (Continued)

SOURCE	EXTERNAL		INTERNAL	
	Individual dose (mrem/y)	Population dose (person-rem/y)	Individual dose (mrem/y)	Population dose (person-rem/y)
Fallout	$^{f}2$	-	-	-
Uranium Fuel Cycle	-	2014	-	-
Mining and milling	-	-	$^{g}4.5x10^{-2}$	2.5
Fuel enrichment	$^{h}0.17$	14	$^{i}4.3-8.0$	$^{j}14$
Fuel fabrication	-	-	$^{k}2x10^{-3}$	$^{k}3$
Power reactors BWR	$^{m}54$ max	$^{n}1552$	-	-
PWR	$^{m}1$ max	$^{n}155$	-	-
Research reactors	-	-	-	-
Transportation -				
Nuclear power industry	-	$^{o}100$	-	-
Radioisotopes	-	$^{o}170$	-	-
Reprocessing and spent fuel storage	$^{p}5.8$	$^{p}23$	-	-
Radioactive waste disposal	-	-	-	-
Federal Facilities	-	1.96	-	-
ERDA	$^{m}13-320$	$^{n}8x10^{-7}$ -1.96	-	-
Department of Defense	0.01	-	-	-
Accelerators	$^{m}0.04-4$	0.42-65	-	-
Radiopharmaceuticals-production and Disposal	0.2	$^{q}0.083$	-	-

a Uranium-238 series
b Thorium-232 series
c Lung dose
d Lung-rem/y
e Trachea-bronchial dose
f 50 year dose commitment divided by 50
g Average individual lung dose within 80 km
h Maximum potential exposure
i Maximum potential exposure to lung
j Cumulative exposure within 40 mile radius
k Average individual lung dose within 80 km
m Fence line boundary dose
n Within a radius of 80 km
o Estimated for the year 1973
p For NFS
q Based upon data from 5 institutions
r Millirads/y
s Estimated 1980 dose
t Average occupational exposure/y
u Average exposure for all occupations & 3.7 radiation workers/1000 persons in United States
v 5 cm from TV set; units of mR/h
- = No dose data available

radionuclides, usually in the uranium series, and agricultural uses can result in runoff. Thorium has varied industrial uses. Historically, radium has been used for industrial and medical purposes and residual contamination is not uncommon. The major features of contamination by naturally occurring radioactivity are the low specific activity and widespread distribution.

In the second category, that involving the application of nuclear technology, the potential impact on the environment is characterized by the production of concentrated, high specific activity materials. A prime example of this is the nuclear fuel cycle. The fuel rods mentioned above are placed into nuclear reactors and the uranium induced to fission. The fission process creates large, concentrated amounts of radioisotopes. In normal operations, small amounts of these radioactive materials may be released into the atmosphere or into surrounding waters. Pollution control measures remove some of this material which is disposed of as low level waste. Catastrophic failure of a reactor may, of course, release substantial amounts of radioactivity. The fuel rods must be replaced periodically and since these "spent" rods are highly radioactive, they must be cooled for long periods of time in order to prevent their melting. In some instances, the spent fuel is reprocessed to remove useful isotopes and the residue disposed of as high level waste. Most of the commercial spent fuel in this country will be disposed of, intact, as high level waste.

The production of radioisotopes may also be accomplished in particle accelerators. While the quantities involved are smaller than in the reactor, substantial amounts of specific isotopes may be produced for industrial and medical use. While such material is normally tracked carefully, inadvertent releases to the environment are not unknown. By contrast with the naturally occurring series, the major aspect of nuclear technology applications is the localized occurance of high specific activity material.

Releases

Due to the complexity of the releases from various sources; it is difficult to characterize them in readily understandable form. That is, while detailed descriptions of the radioactive material released in different operations are available, the large numbers of radioisotopes involved tend to obscure their overall impact. A more suitable measure of potential exposure is the average radiation dose (the energy deposited per unit mass of tissue) from each type of operation. Table 1 shows the average annual external and internal doses expected for the industrial sources listed. These doses are calculated for humans - the dosimetry for most other flora and fauna is not well established - but are indicative of the relative magnitudes of the impact on other parts of the environment. Radiation doses are usually stated in terms of roentgens and rem - both a measure of the energy deposited per unit mass of the receptor. Multiples used in Table 1 and in the discussion below are milli (1/1000), and kilo (1000) rad or rem.

Ecological Risk

One would expect two major types of radiation effects at the community level (community being a natural grouping of vegetation and animals). There should be an increase in the frequency of deleterious mutations and cancer and a decrease in the survival and vigor of the irradiated organisms - both of which are very dose dependent. However, despite the increase in mutations following acute or short term irradiation, the overall genetic consequences may be of lesser importance than the acute effects on the organisms. Most mutants would be similar to those that occur spontaneously and would not be new to the population. They would be present in increased numbers. If the radiation exposure is of limited duration such that it does not produce a long term change in the mutation rate (and if breeding is at random, and if selective forces within the ecosystem are not changed), then the incidence of a given mutant gene should become stabilized at the level determined by the pressures of natural selection, like that of any spontaneous mutation. There should be no long term major increase in mutations. However, with continuing or chronic irradiation, the increased incidence of mutant genes could be sustained in the population.

In the US, exposures, absorbed doses, and dose equivalents have historically been expressed in units of Roentgen (R), rad, or rem respectively. Roentgen is a unit of exposure for x-rays; a one rad absorbed dose in small animals, up to dog size, and equivalent to 0.5 to 0.7 rad in large animals. Rad is a unit of absorbed dose; a 1 rad absorbed dose is equivalent to a 1 rem dose equivalent for x-rays and gamma rays and equivalent to 10 to 20 rem for alpha particles. Rem is a unit of radiation dose equivalent that is, 1 rem of any type of ionizing radiation yield the same long term effects.

Acute Exposure

It is likely that the major effect on a community is related to the survival and vigor of the irradiated organisms. Based on laboratory experiments, the radiosensitivities of the various populations in a community are roughly: lethal exposure for most mammals 200 R to 1000 R, fishes 1000 R to 10 kR; marine animals 1000 R to 70 kR; insects 1000 R to 100 kR; flowering plants 1000 R to 150 kR; and microorganisms between a few kR and a million R (Vo81, IAEA73, Ne71, An86).

On land, the animals and motile insects are dependent on the plants, thus they will move into or out of an area as the population of plants changes. Therefore, unless the mobility or availability of the animals is restricted naturally or artificially, most changes in communities are associated with alterations in the plant population. It has been determined that herbaceous species are more radioresistant than woody species and that dormant plants are appreciably more resistant than the same plants when actively growing. In addition, the radiosensitivity of a plant species has been shown to be related to the interphase chromosome volume of the meristematic cells (Sp65).

In general, the gymnosperms have much higher chromosome volumes and therefore, presumably are more radiosensitive than the angiosperms. In other words, "pine-type" forests would be more sensitive than deciduous or "hardwood" forests - LD_{100} values range from 500 R to 13 kR respectively (Ne71).

Low exposures may inhibit growth and reproductive capacity of sensitive species temporarily but recovery should be rapid and there should be no change in the composition of the plants. It is possible that secondary damage could occur from radioresistant-opportunistic insects or microorganisms but even this effect would be short lived and the damage minor. Excluding severe effects produced by massive exposures sufficient to reduce the capacity of the site for supporting life, there should be established an orderly succession leading to an ecosystem basically similar to the system damaged.

These acute effects estimates are included only to assure completeness in the review of possible effects. Radiation exposures in the environment of such magnitude are not expected, bar major nuclear accident or nuclear war.

Chronic Exposure

Although there is a fair amount of data on the acute effects of high levels of radiation on components of ecosystems less is known of chronic effects.

Mutation rates in plants of 10^{-7} to 10^{-9} per rad per locus; in insects of 10^{-6} to 10^{-8} per rad per locus and in mammals of 10^{-6} to 10^{-8} per rad per locus have been reported (UNSCEAR 72,77). The French have reported that the dose response for genetic effects in some terrestrial plants is linear from background levels (10 µrad per hour) to about 10,000 µrad per hour. Mutation rates increased 10^{-7} to 10^{-8} per µrad/hr increase in exposure (De80).

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Impairment of reproductive and developmental functions and genetic integrity have been observed in snail and fish populations at exposure levels of less than 1 rad/day (Bl66a, 66b, Hy80, Do64). However, other effects that might be considered, hormesis have been noted starting at about 0.5 rad/day (Do64, Wi71).

Ectoparasites have been more numerous on rodents and lizards exposed to elevated levels of chronic radiation than on controls in the desert ecosystem at the Nevada Test Site (Al62a, 62b). Ectoparasites on birds and mammals have been more numerous in high natural radiation areas than in background radiation areas in Northern taiga zones in Russia (Ma67).

The life span of pocket mice living in a radiation field of 1 to 2 rad/day was shorter than in control areas (Fr69, Fr70) and some female lizards became sterile (Fr70). Degenerative changes, reproductive and developmental problems have been reported in animals in high natural background areas compared to normal areas. These changes occurred not only in animals in intimate contact with the soil, ie., burrowing mammals, but also in carnivores and birds with less intimate ground contact (Ma67). Hovever, the possible contribution of radon daughters to burrowing animal exposure was not evaluated. Thus, it appears, in addition to the genetic and carcinogenic effects, one would expect other detriment may occur in individuals in the ecosystem exposed to ionizing radiation.

As noted earlier sources of increased radiation exposure in the environment include: normal releases from nuclear reactors, disposal of low level radioactive wastes, disposal of mine spoils and mill tailings, disposal of soil contaminated with natural radioisotopes, etc. Estimates of doses to various components of the ecosystem are not available for most sources. However, doses due to water discharges from some nuclear reactors have been estimated. The estimates of maximum radiation doses to biota in the vicinity of various reactors range from 8 to 15,000 mrad/year for freshwater and marine plants; 1 to 6100 mrad/yr in mollusks and crustaceans; 1 to 1800 mrad/yr in fin fish and 3 to 62000 mrad/yr in muskrats, waterfowl and shore birds (Ka73).

Even though estimated detriment to individuals or populations could be calculated, there are no criteria against which to measure the estimated detriment. There is no criterion to decide at what level of mutation load the situation should be considered serious; no criterion for assessing what species or diversification of species is considered good or bad, or what the changes would mean; no criterion for how large an area must be affected before it is worrisome, etc. The same is true for carcinogenesis, reproductive and developmental impairment or any other detriment.

Likewise if reduced immuno-competency is indicated, suggesting increased risk of zoonotic and/or indigenous disease, at what level does this effect become important?

Until some criteria of impact are developed the expected effect of radiation on ecosystems should be considered undefined. While the effect has historically been considered minimal and emphasis has been on pathways through ecosystems that might effect man, radiation does have the potential of causing disruption in ecosystems. The magnitude of disruption would be expected to be related to the level and duration of exposure. If there were criteria for evaluating severity it might be possible to determine the grading of radiation sources more exactly.

To the extent to which the question of the potential ecological impact of various radiation sources has been examined in the United States, there do not seem to be any ecological disruptions. There may be areas of high background exposure but these will usually be associated with high radon areas and are expected to involve relatively small areas.Likewise reactor liquid discharges, tailings piles, mine spoils and overburdens, contaminated areas, etc. involve only small areas of land. Possible ocean dumping of radioactive materials is a source of potential impact which should be considered more seriously.

"Conventional wisdom" has been - if man is protected the environment is protected. While this appears to be true it would be nice to have ecological evaluation criteria to prove or disprove this "wisdom".

III. Assessment

Overall, the impact of anthropogenic radioactivity would appear to be minimal. Most potential sources are already closely controlled and monitored. The current contribution from human activities to the total radiation environment is small. If the non-anthropogenic radiation dose is taken to be about 200 mrem per year, then fallout is approximately 10 percent of that with nuclear activities adding another 1 percent. This conclusion must be conditioned by the knowledge that the long term effects of low level radiation are not well known and that severe accidental releases may have large local consequences coupled with more extensive, but lesser, global effects. At present, however, this ecological problem should be rated as low.

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REFERENCES

Al62a Allred, D.M. and Beck, D.E. Ecological Distribution of Mites on Lizards at the Nevada Atomic Test Site. Herpetol, 18:47-51 (1962).

Al62b Allred, D.M. Mites on Squirrels at the Nevada Atomic Test Site. J. Parasitol, 48:817 (1962).

An86 Anderson, S.L. and Harrison, F.L. *Effects of Radiation on Aquatic Organisms and Radiobiological Methodologies for Effects Assessment*, EPA 520/1-85-016. US Environmental Protection Agency, Washington, D.C. 1986.

Bl66a Blaylock, B.G. Chromosomal Polymorphism in Irradiated Natural Populations of *Chironomus*. Genetics, 53:131 (1966).

Bl66b Blaylock, B.G. Cytogenetic Study of a Natural Population of *Chironomus* Inhabiting an Area Contaminated by Radioactive Waste, pp. 835-846 in *Proc. Symp*., *Disposal of Radioactive Wastes into Seas, Oceans, and Surface Waters*, International Atomic Energy Agency, Vienna, 1966.

De80 Delpoux, M., Fabries, M., Faure, F., Dulieu, H., Leonard, A. and Dalebroux, M. Study of Genetic Effects in Plants Induced by Natural Radioactivity in Southwest France, pp. 1072-1076 in *Natural Radiation Environment III*, *Vol 2*, CONF. 780422, T.F. Gesell and W.M. Lowder, editors, US Department of Energy, Washington, D.C., 1980.

Do64 Donaldson, L.R. and Bonham, K. Effects of Low-Level Chronic Irradiation of Chinook and Coho Salmon Eggs and Alevirs, Trans. Am. Fish. Soc., 93:333 1964.

Fr69 French, N.R., Maza, B.G. and Kaaz, H.W. Mortality Rates in Irradiated Rodent Populations, pp. 46-52, in *Symposium on Radioecology*, CONF. 670503, D.J. Nelson and F.C. Evans, editors, US Atomic Energy Commission, Washington, D.C., 1969.

6

Fr70 French, N.R., Chronic Low-Level Gamma Irradiation of a Desert Ecosystem for Five Years, pp. 1151-1167; in Proc. Symp. International de Radioecologie Cadarache, France, CONF. 690918, A. Grauby, editor, US Atomic Energy Commission, Oak Ridge, TN., 1970.

Hy80 Hyods-Taguchi, Y., Effects of Chronic Y-Irradiation on Spermatogenesis in the Fish Oryzias Latipes, with Special Reference to Regeneration of Testicular Stem Cells, pp. 91-104, in Radiation Effects on Aquatic Organisms, N. Egami, Editor, (Japan Scientific Societies Press, Tokyo: University Park Press, Baltimore, Md.) 1980.

IAEA73 Environmental Behavior of Radionuclides Released in the Nuclear Industry, Proceedings of a Symposium organized by the IAEA, the OECD Nuclear Energy Agency and the World Health Organization, May 14-18, 1973

Ka73 Kaye, S.V. Assessing Potential Radiological Impacts to Aquatic Biota in Response to the National Environmental Policy Act (NEPA), pp. 649-661, in Environmental Behavior of Radionuclides Released in the Nuclear Industry, International Atomic Energy Agency, Vienna, 1973.

Ma67 Maslov, V.I., Maslova, K.I. and Verkhouskaya, I.N. Characteristics of the Radioecological Groups of Mammals and Birds of Biogeocoenoses with High Natural Radiation, pp. 561-571 in Radioecological Concentration Processes, B. Aberg and F.P. Hungate, editors, Pergamon Press, New York, 1967.

Ne71 Radionuclides in Ecosystems, Proceedings of the Third National Symposium on Radioecology May 10-12, (1971); Oak Ridge, TN., Vol I and 2, D.T. Nelson, editor, US AEC CONF-710501-P1&P2, 1971.

Sp65 Sparrow, A.H., Relationship Between Chromosome Volume and Radiosensitivity in Plant Cells; pp. 199-222, in Cellular Radiation Biology, Williams & Wilkins Co., Baltimore, MD. (1965).

Vo81 *Natural Radiation Environment*, Proceedings of the Second Special Symposum on Natural Radiation Environment; Jan. 19-23, 1981. Ed. by K.G. Vohra, U.C. Mishra, K.C. Pillai & S. Sadasivau, John Wiley & Sons, 1982

Wi71 Williams, B., and Murdock, M.B., The Effects of Contineous Low-Level Gamma Radiation on Estuarne Microcosms pp. 1213-1221 *Proc. of Third Nat'l. Symposium on Radioecology*, *Vol. 2*, CONF. 710501, US Atomic Energy Commission, Oak Ridge, TN, 1971.

Wo77 Woodhead, D.S. The Effects of Chronic Irradiation on the Breeding Performance of the Guppy, *Poecilia reticulata* (Ostcichthys: Teleostei), Int. J. Radiat. Biol. *32*:1, (1977)

Problem 7. Stratospheric Ozone Depletion

OVERVIEW

Human activites are increasing the global atmospheric concentrations of chlorofluorocarbons (CFCs), carbon dioxide, methane, and several other trace gases. A growing body of scientific evidence suggests that increasing concentrations of these gases may deplete the stratospheric ozone layer, which shields the earth from harmful ultraviolet radiation (UV-B). Increases in UV-B could adversely affect terrestical and aquatic ecosystems. Additional stresses could result from the links between trace gas concentrations, changes in stratospheric structure, and global climate change (see Problem # 8).

SOURCES AND QUANTITIES OF POLLUTANTS RELEASED

The main anthropogenic cause of ozone depletion is attributed to CFCs, a family of compounds used worldwide as aerosol propellants, foam blowing agents, refrigerants, and solvents. World production of CFC-11 and CFC-12, the most commonly used CFCs, was 703 million kilograms in 1985, up from 695 million kilograms in 1984. In developed countries, historical use of CFCs has kept pace with economic growth -- annual changes in CFC use have averaged approximately twice the growth rate of GNP. Other CFCs, particularly CFC-113, which is used in the electronics industry, have grown much faster. CFCs persist in the atmosphere. The lifetimes of CFC-11 and CFC-12 are 75 years and 150 years. Virtually all CFCs manufactured are eventually released to the atmosphere.

ECOLOGICAL EFFECTS AND ASSESSMENT

Recent modelling results show that if CFCs and other trace gases grow at recent rates, global average ozone depletion could reach 6.5 percent by the year 2030. However, depletion would vary by season and latitude. Regions such as the Northern U.S. and Northern Europe would experience significantly higher depletion. At 60 degrees North, depletion could reach 16 percent in Spring. Even with constant CFC emissions, annual average depletion would reach 8 percent in the high Northen latitudes. A one percent depletion of ozone leads to roughly a two percent increase in harmful UV-B radiation.

Increases in UV-B would affect both aquatic and terrestial ecosystems. The aquatic resources most affected by UV-B would be phytoplankton and larvae of several fish species, particularly crabs, fish, and anchovies. Of the more than two hundred terrestial plants that have been tested in the laboratory, two-thirds have reacted adversely to increased UV-B. These and other far more limited field tests suggest that some cultivars may be more susceptible to UV-B damage than others. For both aquatic and terrestial ecosystems, both the productivity of particular species and the competitive balances among different species would be affected.

Problem #7 Stratospheric Ozone Depletion

Human activities are increasing the worldwide atmospheric concentrations of chlorofluorocarbons, carbon, dioxide, methane, and several other gases. A growing body of scientific evidence suggests that if these trends continue, stratospheric ozone may decline and global temparature may rise. Because the ozone layer shields the earth's surface from damaging ultraviolet radiation (UV) future depletion could increase the incidence of skin cancer and other diseases, reduce crop yields, damage materials, and place additional stress on aquatic plants and animals. This additional stress would result in part because some of the same trace gases which affect stratospheric ozone are also "greenhouse" gases linked with a rapid global warming (see problem #8 - CO_2 and Global Warming).

Atmospheric Processes

The ozone in the upper part of the atmosphere--known as the stratosphere--is created by ultraviolet radiation. Ordinary oxygen (O_2) is continuously converted to ozone (O_3) and back to O_2 by numerous photochemical reactions that take place in the stratosphere as Stordal and Isaksen (1986) describe. Chlorofluorocarbons and other gases released by human activities could alter the current balance of creative and destructive processes. Because CFCs are very stable compounds, they do not break up in the lower atmosphere (known as the troposphere). Instead, they slowly migrate to the stratosphere, where ultraviolet radiation breaks them down, releasing chlorine.

Chlorine acts as a catalyst to destroy ozone; it promotes reactions that destroy ozone without being consumed. A chorine (Cl) atom reacts with ozone (O_3) to form ClO and O_2. The ClO later reacts with another O_3 to form two molecules of O_2, which releases the chlorine atom. Thus, two molecules of ozone are converted to three molecules of ordinary oxygen, and the chlorine is once again free to start the process. A single chlorine atom can destroy thousands of ozone molecules. Eventually, it returns to the troposphere, where it is rained out as hydrochloric acid. Atmospheric models are utilized to examine possible future changes to the ozone layer from increased atmospheric concentrations of CFCs and other gases.

At a recent conference sponsored by EPA and UNEP, Stordal and Isakson presented results of possible ozone depletion over time, using their two-dimesional atmospheric chemistry model. Unlike one-dimensional models which provide changes in ozone in the global average, this model calculates changes for specific latitudes and seasons. The results show that if concentrations of the relevant trace gases grow at recent levels, global average ozone depletion by 2030 would be 6.5 percent. However, countries in the higher latitudes (60°N) would experience 16 percent depletion during spring. Even in the case of constant CFC emissions, where global average depletion would be 2 percent by 2030, average depletion would be 8 percent in the high northern latitudes.

Watson (1986) presents evidence that ozone has been changing recently more than atmospheric models had predicted. The ozone over Antarctica during the month of October appears to have declined over 40 percent in the last six to eight years. Watson also discusses observations from ozone monitors that suggest a 2 to 3 percent worldwide reduction in ozone in the upper portion of the stratosphere (thirty to forty kilometers above the surface), which is consistent with model predictions. Whether or not these changes are directly related to CFCs has not been scientifically established to date.

Sources and Quantities Released

The major anthropogenic cause of ozone depletion is attributed to chlorofluorocarbons (CFC) a family of compounds used world wide for aerosol propellants, rigid foams, flexible foams, refrigeration, air conditioning and industrial cleaning. Production of CFC 11 and 12, the most commonly used CFCs was 703,200 metric tons in 1985, up from 694,500 metric tons in 1984. The yearly increase in world production averages about 2 to 3% per year and has increased at this level since production began in the 1950s. Lifetime persistance in the atmosphere for CFC 11 is 75 years, and for CFC 12 is 110 years. Virtually all CFC's manufactured eventually are released into the atmosphere.

Affects on Aquatic Organisms

Aquatic plants would likely be adversely affected by increased ultraviolet radiation. Worrest (1986) points out that most of these plants, which are drifters (phytophlankton), spend much of their time near the surface of the water (the euphotic zone) and are therefore exposed to ultraviolet radiation. A reduction in their productivities would be important because these plants directly and indirectly provide the food for almost all fish. Although these plants might move deeper to avoid UV-B radiation, such shifts would reduce their photosynthetic productivity. Furthermore, the larvae of many higher order fish which are found in the euphotic zone would be directly affected, including crabs, shrimp, and anchovies. Worrest points out that fish account for 18 percent of the animal protein that people around the world consume, and 40 percent of the protein consumed in Asia.

An important question is the extent to which current UV-B levels are a constraint on aquatic organisms. Calkins and Keller (1984) conclude that some species are already exposed to as much UV-B as they can tolerate. Thomson (1986) shows that a 10 precent decrease in ozone could increase the number of abnormal larvae as much as 18 percent. In a study of anchovies, a 20 percent increase in UV-B radiation over a 15-day period caused the loss of all the larvae within a 10-meter mixed layer in April and August. Increased UV-B radiation could not only have serious direct effects on aquatic organisms but also serious indirect effects as significant reductions in the populations of lower trophic level organisms alters the competitive balance of organisms at higher tropic levels. Serious changes in community structure and function could result. This impact would be global in scope, continuous and irreversible.

Effects on Plants

The effects of increased exposure to UV-B radiation on plants has been a primary area of research for nearly a decade. Teramura (1986) reports that of the two hundred plants tested for their sensitivity to UV-B radiation, over two-thirds reacted adversely; peas, beans, squash, melons, and cabbage appear to be the most sensitive. Given the complexities in this area of research, he warns that these results may be misleading. For example, most experiments have been in growth chambers. Studies of plants in the field have shown them to be less sensitive to UV-B.

Bjorn (1986) examines the mechanisms by which plant damage occurs. His research relates specific wavelengths with those aspects of plant growth that might be susceptible, including the destruction of chloroplast, DNA, or enzymes necessary for photosynthesis. Increased UV-B radiation could substantially alter the competitive balance favoring vegetation that is less sensitive to UV-B radiation, which would come to dominate. Serious changes in community structure and function would likely result. This potential impact would be global in scope, and continuous.

CLIMATE CHANGE

The Greenhouse Effect

Concern about a possible global warming focuses largely on the same gases that may modify the stratospheric ozone: carbon dioxide, methane, CFCs, and nitrous oxide. The report of a recent conference convened by UNEP, the World Meteorological Organization, and the International Council of Scientific Unions concluded that if current trends in the emissions of these gases continue, the earth could warm a few degrees (C) in the next fifty years (Villach 1985). In the next century, the planet could warm as much as five degrees (NAS 1983), which would leave the planet warmer than at any time in the last two million years. For a complete discussion of the global warming impacts on ecosystems, see problem #8, "CO_2 and global warming".

Controllability

Because there are time lags of decades between changes in emission rates, atmospheric concentrations, and changes in ozone, the types of management strategies must be different from those that are appropriate for controlling, for example, particulate pollution, where the problem goes away as soon as emissions are halted. CFC emissions would have to be cut 80 percent simply to keep atmospheric concentrations from increasing. Considerable reduction in CFCs are possible through existing technologies including: carbon absorption, reduced leakage, and substitute products and chemicals. Moreover, the production of more benign CFCs may be possible within the next decade.

Assessment

Doniger and Wirth, from the Natural Resources Defense Council (U.S.), argue that the current uncertainties are no longer a reason to wait for additional information: "With the stakes so high, uncertaintly is an even more powerful argument for taking early action." These authors conclude that sharp reductions in CFCs are necessary, pointing out that even with a production cap, atmospheric concentrations of these gases will continue to grow. Therefore, Doniger and Wirth propose an 80 percent cut in production over the next five years for CFCs 11 and 12, the halons, and perhaps some other compounds, with a complete phaseout in the next decade.

Gus Speth, president of the World Resources Institute, recommends a production cap for chlorofluorocarbons and agrees with Topping that environmental impact statements for projects that could contribute to ozone modification should consider these impacts.

The severity of the potential ecological impacts that could result from increased UV-B radiation, the global scale of such impacts and their irreversibility more than offsets the associated uncertainties. This environmental problem is global in scale, and its intensity of impact on ecosystems is potentially very high.

References

Calkins, J., and C.I. Keller (1984) "Solar UV and its Impact on Microorganisms in Aquatic Ecosystems", prepared for the U.S. EPA.

Stordal, Frode and Ivan Isakser; "Ozone Perturbations Due to Increases in N_2O, CH_4 and Chlorocarbons: Two-dimensional Time Dependent Calculations" in Effects of Changes in Stratospheric Ozone and Global Climate, Vol. I Overview, U.S. EPA, August 1986.

Teramura, A.H. (1986) "Overview of Our Current State of Knowledge of UV Effects on Plants", in EPA (1986), Effects of Changes in Stratospheric Ozone and Global Climate. Volume I: Overview, U.S. EPA, Washington, D.C.

Thomson, B.E.; "____________", in Effects of Changes in Stratospheric Ozone and Global Climate, Vol. II: forthcoming

Villach, (1985) International assessment of the role of carbon dioxide and of other greenhouse gases in climate variations and associated impacts. Conference Statement. Geneva: United Nations Environment Program.

Watson, Robert; "Atmospheric Ozone" in Effects of Change in Stratospheric Ozone and Global Climate, Vol. I: Overview, U.S. EPA, August 1986.

Worrest, R.C. (1986) "The Effect of Solar UV-B Radiation on Aquatic Systems: An Overview", in EPA (1986), Effects of Changes in Stratospheric Ozone and Global Climate. Volume I: Overview, U.S. EPA, Washington, D.C.

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Problem 8. CO_2 and Global Warming

OVERVIEW

In recent decades, the concentrations of greenhouse gases have been increasing. Since the industrial revolution, the combustion of fossil fuels, deforestation, and other anthropogenic influences have released enough CO_2 into the atmosphere for concentrations to rise 20 percent since the late 19th century -- 8 percent since 1958. An international conference of scientists and policymakers recently convened in Villach Austria and concluded that by the year 2030, increases in CO_2 and other greenhouse gases, particularly chlorofluorocarbons (CFCs), methane, and nitrous oxide, would ensure a global temperature increase of 1.5 to 4.5 degrees Centigrade. An increase of this size and speed is unprecented in human history.

CONCENTRATIONS OF POLLUTANTS RELEASED

Increases in future CO_2 emissions are expected as future economic and population growth contribute to increased fossil fuel combustion and deforestation. An analysis prepared for the National Academy of Sciences projects that by the year 2065, atmospheric CO_2 concentrations will have reached twice the pre-industrial level. The concentrations of other greenhouse gases are also increasing: CFC-11 and CFC-12 at 5 percent per year, methane at 1 percent per year, and nitrous oxide at 0.2 percent per year. As with CO_2, emissions are related to population and economic growth, and future increases are likely.

ECOLOGICAL EFFECTS AND ASSESSMENT

A change in global climate of the size and speed forseen at the Villach Conference would have major implications for ecosystems. One of the most widely recognized consequences would be a rise in sea level resulting from thermal expansion of the oceans, and changes in ice fields. By the year 2100, a rise in sea level of 90 to 170 centimeters is likely. Such an increase would innundate low-lying areas, destroy coastal marshes and swamps, erode shorelines, exacerbate coastal flooding, and increase the salinity of rivers, bays and aquifiers.

Changes in temperature and key hydrological variables such as precipitation, evaporation, soil mositure and runoff would have serious implication for terrestial ecosystems. Changes in net biomass and biomass composition are also likely.

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Problem # 8 - CO_2 and Global Warming

In recent decades, the concentrations of greenhouse gases have been increasing. Since the beginning of the industrial revolution, the combustion of fossil fuels, deforestation, and a few other activities have released enough CO_2 to raise atmospheric concentrations by 20 percent; concentrations have risen 8 percent since 1958 (Keeling, Bacastow, and Whorf 1982). More recently, Ramanathan et al. (1985) examined the greenhouse gases other than CO_2 (such as methane, CFCs, and nitrous oxide), and concluded that these other gases are likely to double the warming caused by CO_2 alone. Using these results, the Villach Conference estimated that an "effective doubling" of CO_2 is likely by 2030.

This increase will cause global temperatures to increase 1.5°-4.5°C over the next 50-75 years. Such a rapid climate change is unprecedented. The magnitude of change is roughly equivalent to the difference between the last Ice Age (18,000 years ago) and today.

Sources and Quantities Released

The total quantity of CO_2 emitted is calculated as the product of fuel used in each time period and CO_2 emitted per unit quantity of each fuel. The following CO_2 (carbon) emission coefficients are employed (Edmonds and Reilly, 1983a):

CO_2 Emissions (Terragrams of Carbon/EJ)

Fuel	Preparation	Combustion	Total
Conventional Oil	--	19.7	19.7
Unconventional Oil (Shale Oil)	27.9	19.7	47.6
Gas	--	13.8	13.8
Coal	--	23.9	23.9
Synthetic Oil (from coal)	18.9	19.7	38.6
Synthetic Gas (from coal)	26.9	13.9	40.7

All other fuels are assumed to contribute no CO_2 to the atmosphere.

The amount of CO_2 in the atmosphere has been steadily increasing for several decades as indicated by the graph on the next page.

Nitrous oxide (N_2O) emissions result primarily from combustion of fossil fuels and biological dentrification processes in soil. By increasing the use of nitrogen fertilizers and by adding nitrogen-rich sewage to water bodies, we are indirectly adding nitrous oxide to the atmosphere. Measurements of N_2O concentrations from 1970 to 1980 show an increase of 6 parts per billion (ppb) to a level of 295 ppb (Lacis, 1981). Estimates suggest that a doubling of nitrous oxide would directly increase temperature by 0.30-0.44°C (Donner and Ramanathan, 1980; Wang and Sze, 1980). In addition, increases in N_2O may indirectly contribute to an even greater warming. Wang and Sze have calculated that the resulting indirect greenhouse warming could raise temperature another 0.18°C for a total increase of 0.48-0.62°C due to a doubling of N_2O.

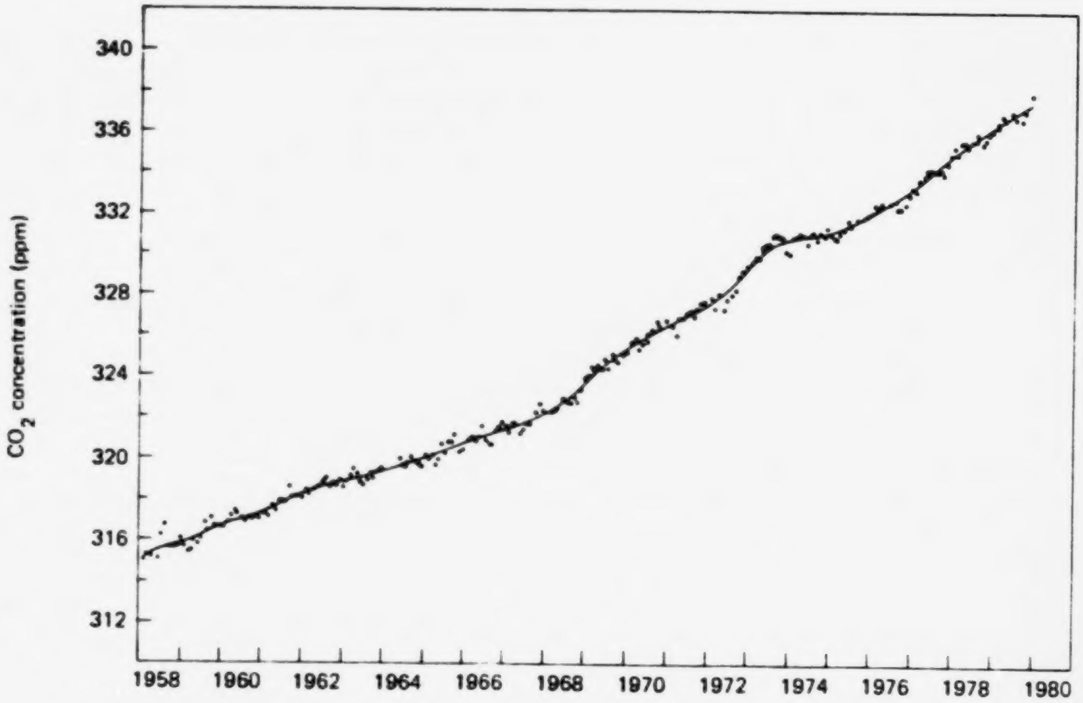
As more fossil fuels are used, N_2O emissions are likely to increase. Also as greater demands are placed on world food supplies, increased use of nitrous oxide-producing fertilizers is likely. However, because the natural sources and sinks of this trace gas are not well understood, more research is required before reliable projections can be made of future levels.

METHANE

Methane (CH_4), is a second important trace greenhouse gas. The known sources of CH_4 are anaerobic fermentation in rice fields and swamps, and enteric fermentation from termites, cows, and other animals. As the need for food from livestock and rice fields increases over time, atmospheric levels of CH_4 are likely to increase. In addition, increases in carbon monoxide (from fuel combustion) in the troposhere lowers the concentration which destroys methane. Based on current estimates of a 2 percent per year increase in concentration, by the middle of the next century CH_4 could increase global warming by about 0.2-0.3°C (Lacis, 1981).

Future increases in methane could, however, be far higher than the estimated 2 percent per year of the recent past. As the earth warms, extensive peat bogs containing as much as 2000 gigations of CH_4 in the form of methane hydrates now frozen in northern latitudes may thaw, releasing considerable quantities of this gas into the atmosphere. While much of

MONTHLY ATMOSPHERIC CARBON DIOXIDE CONCENTRATION AT MAUNA LOA OBSERVATORY*



*Seasonal effects have been normalized.

Source: CEQ (1981), based on data derived from Keeling, Scripps Institute of Oceanography.

this methane is buried 250-1,000 meters under the ground and therefore, unlikely to be released for several centuries, a contribution of eight gigatons per year from methane hydrates under shallow water is possible within the next 100 years (Bell, 1982).

For quantitative information on CFCs, see problem #7 "Stratospheric Ozone Depletion."

Effects on Fresh Water Resources - Lakes, Rivers and Wetlands

There is evidence that climate change since the last Ice Age 18,000 years B.P. has significantly altered the location of lakes although the extent of present day lakes is broadly comparable with 18,000 years B.P. For example, there is evidence indicating the existence of many lakes and swamps in the Sahara, Arabian and Thor Deserts around 9-8,000 years B.P.

The inextricable linkages between the water cycle and climate insure that potential future climate change will significantly alter hydrological processes throughout the world. All natural hydrological processes -- precipitation, infiltration, storage and movement of soil moisture, surface and subsurface runoff, recharge of groundwater and evaporranspiration -- will change if climate changes.

As a result of changes in key hydrological variables such as precipitation, evaporation, soil moisture and runoff; climate change is expected to have significant effects on water availability. Early hydrological impact studies provide evidence that relatively small changes in precipitation and evaporation patterns might result in significant, perhaps critical, changes in water availability. For many aspects of water resources -- including human consumption, agricultural water supply, flooding and drought management, groundwater use and recharge and reservoir design and operation--these hydrologic changes will have serious implications.

Despite significant differences among climate change scenarios, a consistent finding among hydrologic impact studies is the prediction of a reduction in summer soil moisture and the timing and magnitude of runoff. Winter runoff is expected to increase and summer runoff may decrease.

Effects on Coastal Estuaries and Tidal Wetlands

One of the most widely recognized consequences of a global warming would be a rise in sea level. As Titus (Volume 1) notes, global temperatures and sea level have fluctuated over periods of one hundred thousand years, with temperatures during ice ages being three to five degrees (C) lower and sea level over one hundred meters lower than today. By contrast, the last interglacial period (one hundred thousand years ago) was one or two degrees warmer than today, and sea level was five to seven meters higher.

The projected global warming could raise sea level by heating and thereby expanding ocean water, melting mountain glaciers, and by causing polar glaciers in Greenland and Antarctica to melt and possibly slide into the oceans. Thomas (Volume 4) presents new calculations of the possible contribution of Antarctica and combines them with previous estimates for the other sources, projecting that a worldwide rise in sea level of 90 to 170 centimeters by the year 2100 with 110 centimeters most likely. The projected rise in sea level would inundate low-lying areas, destroy coastal marshes and swamps, erode shorelines, exacerbate coastal flooding, and increase the salinity of rivers, bays, and aquifers.

Park et al. (Volume 4) focus on the expected drowning of coastal wetlands in the United States. Using a computer model of over 50 sites, they project that 40-75 percent of existing U.S. coastal wetlands could be lost by 2100. Although these losses could be reduced to 20-55 percent if new wetlands form inland as sea level rises, the necessary wetland creation would require existing developed areas to be vacated as sea level rises, even though property owners would frequently perfer to construct bulkheads to protect their property. Because coastal wetlands are important for many commerically important seafood species, as well as birds and furbearing animals, Park et al. conclude that even a one-meter rise in sea level would have major impacts on the coastal environment.

DeSylva (Volume 4) also examines the environmental implications of sea level rise, noting that in addition to wetlands being flooded, estuarine salinity would increase. Because 66 to 90 percent of U.S. fisheries depend on estuaries, he writes that these impacts could be important. He also suggests that coral reefs could become vulnerable because of sea level rise, increased temperatures, and the decrease in the pH (increased acidity) of the ocean.

Effects on Terrestrial System

The greenhouse warming could affect agriculture by altering water availability, length of growing season, and the number of extremely hot days. Global climate change would also likely alter the composition of biomass significantly. Solomon predicts a net decline in forest biomass of 10% (11 MT/HA). A potential shift of the lobolly Pine region is also predicted.

Predicted decreases in summer soil moisture and increases in the frequency of prolonged high temperature events would likely have significant impacts on the vegetation especially those in marginal lands. The main effects likely to occur will be physical impacts from changes in thermal regimes, moisture stress, and levels and timings of pest infestation.

Controllability

Because there are time lags of decades between changes in emission rates, atmospheric concentrations, and changes in ozone, the types of management strategies must be different from those that are appropriate for controlling, for example, particulate pollution, where the problem goes away as soon as emissions are halted. A worldwide ban on coal instituted by 2000 would reduce temperature change for 2100 by 30% (5°C to 3.5°C). Together, a ban on shale oil and coal would reduce the projected warming in 2100 from 5°C to 2.5°C. Reductions in CFCs would also substantially decrease the projected warming.

Although society is probably locked into a 2°C warming due to past emissions and expected emissions in the next decade, it is not too late to prevent the more disruptive 5° warming. Because of the time lag, however, the difficult and complex international options for limiting the warming must be developed soon if they are to be effective.

Assessment

The severity of the potential ecological impacts that could result from such unprecedented rate of global warming, the global scale of such impacts and their irreversibility warrants serious attention despite the substantial uncertainties that exist regarding the timing of the climate changes and their specific regional and ecological impacts.

References

1. Bell, P.; "Methane Hydrate and the Carbon Dioxide Question" in Clark (ed.), Carbon Dioxide Review 1982, New York: Oxford University Press.
2. Donner L, and V. Ramanathan (1980) "Methane and Nitrous Oxide: Their Effects in Terrestrial Climate", J.J. Atmospheric Science, 37, 119.
3. Edmonds J. and J. Reilly (1983) "A Long Term Global Energy Economic Model of Carbon Dioxide Release from Fossil Fuel Use", Energy Economics, 5, 74.
4. Keeling, C.D., R.B. Bacastow and T.P. Whorf (1982) Measurement of the concentration of carbon dioxide at Mauna Loa, Hawaii, Carbon Dioxide Review, ed. by W. Clark. New York: Oxford University Press.
5. Ramanathan, V., R. Cicerone, H. Singh and T. Kiehl; (1985), Trace gas trends and their potential role in climate change. J. Geophep. Res. 90:5547-66.
6. Titus, J. "The Causes and Effets of Sea Level Rise" in Effects of Changes in Stratospheric Ozone and Global Climate U.S. EPA, August 1986.
7. Wang, W., and N. Sze (1980), "Coupled Effects of Atmospheric N_2O and O_3 in the Earth Climate", Nature 286, 589.

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Problem Sources 9 and 10: Direct and Indirect Point Source Discharges to Surface Waters

Stress Agents

Permitted dischargers to surface waters are collectively the largest source of priority pollutants (organic and inorganic toxicants) being released to the ambient environment. They are also major sources of both conventional pollutants (BOD and TSS), and important nonconventional pollutants such as chlorine and ammonia.

Sources

Approximately 65,000 point sources are permitted to discharge pollutants directly into U.S. waters. Most of these sources are clustered around industrialized population centers in the East and in aggregate constitute a regional problem for this half of the country. Because aquatic resources are limited and industrial development less concentrated west of the Mississippi, problems caused by point sources tend to be somewhat more localized in this region.

Exposures and Impacts

Rough modelling projections of potential ecological impacts from point sources estimate that over 50% of the stream reaches receiving permitted discharges could be deleteriously affected by toxic and/or conventional pollutants. Of the lotic and estuarine waters that have actually been assessed, 40-50% of the impacts are considered due to point sources; impacts to lentic systems are more commonly caused by nonpoint sources.

Current Controls

Most current discharge limits are technology-based rather than water quality-based. Technology-based controls consider the economic feasibility of significantly improving treatment on a national rather than a local scale, and therefore may not be protective of a particular waterbody. Site-specific water quality-based controls are meant to be implemented where additional controls are needed; they are relatively difficult to develop and administer, however, and are not likely to be in place for 5 to 10 years.

Data Quality

Although massive quantities of data are available on chemical effluent and ambient water quality, information on the actual ecological status of aquatic receiving systems is often lacking or inaccessible, and therefore site-specific conclusions should not be drawn. However, at the level of organization most relevant to this project - the national level- the existing data are clearly sufficiently to establish point sources dischargers as a major source of both potential and real impact to aquatic ecosystems.

Overall Importance

As the primary source of toxic pollutants and a major contributor of numerous other stress agents to aquatic systems, point source discharges have an extremely high potential for causing profound and widespread impacts. From an ecological perspective, point source discharges should be one of the highest priority problem areas.

Problem Sources 9 and 10: Direct and Indirect Point Source Discharges to Surface Waters

I. INTRODUCTION

Approximately 65,000 waste treatment facilities are permitted to discharge pollutants directly into the nation's navigable surface waters. Of these, roughly 39,000 have been categorically identified as important sources of both conventional (e.g., BOD, TSS) and toxic pollutants; 24,000 industrial plants and 15,000 POTWs (Table 1). About 17 percent of the POTWs receive significant inputs from the categorical industries (indirect discharges) and are, therefore, of particular concern as potential sources of impact to aquatic ecosystems.

Most point sources are located in the more heavily populated and industrialized regions of the U.S. Figure 1 shows the geographic distribution of the 7,000 largest permitted dischargers; 3,200 industrial plants and 3,800 POTWs. These dischargers are most densely clustered in the midwest and eastern regions of the country where human populations and industrial development have been historically dependent upon abundant aquatic resources. The figure clearly illustrates the profound potential for regional as well as localized impacts from permitted point sources.

As presently regulated, point source controls are implemented through a system of permits (NPDES) which do allow the discharge of both conventional and hazardous materials, but place limits on the amount and concentrations that may be released. Discharge requirements have historically focused on limiting conventional pollutants, and although emphasis has shifted to controlling toxics in the last ten years, most current requirements are technology-based rather than water quality-based. Technology-based controls consider the economic feasibility of significantly improving treatment on a national rather than a local scale and are not specifically designed to protect any given waterbody. Where dischargers are closely clustered or receiving system dilution is low, there remains a significant likelihood of impact, even with full implementation of Best Available Treatment (which is far from complete) and perfect compliance (which is far from true).

Fully regulated discharges are not the only point sources of concern. Regular but unpermitted discharges may be significant in some areas (GAO, 1983), and illegal releases of acutely toxic wastes into aquatic systems may be more common than previously believed (TSD, 1985). Combined sewer overflows and storage impoundments also sporadically release discharges that can cause severe impacts in certain areas.

II. Sources, Stress Agents, and Exposures

Sources

The point source discharge categories considered of primary national importance are listed in Table 1. These categories have been identified as the major dischargers of priority organic and inorganic toxics as well as conventional pollutants. Most of these industries have in-pipe pollutant concentrations that are several times the ambient water quality criteria, and therefore have the potential to cause major impacts, depending on the specific discharge situation. As a single categorical source, POTWs are clearly of primary importance in terms of numbers and post-BAT loadings of both conventionals and toxics. It should be noted that a significant proportion of the total toxics loads discharged from POTWs is contributed by industrial indirect dischargers (13% of all organics and 52% of all inorganics; see Table 2 and "Note", Table 1). This is particularly significant, considering only 17% of the POTWs receive indirect industrial discharges.

Stress Agents

Virtually all of the stress agents identified by the Cornell Workgroup eminate in quantity from point source dischargers. Point sources unquestionably discharge more toxics than any other source and are major contributors to national loadings of BOD, solids, nutrients and chlorine. POTWs are also major dischargers of ammonia which is a potent toxicant to aquatic animals and a source of nitrogenous nutrients to aquatic plants. (Also see Cornell Workshop draft report and Attachment A for brief discussion of stress agents and their general effects on ecosystems)

Exposures

The total number of river reaches receiving major industrial and POTW discharges in each of the nation's 18 hydrologic regions (Figure 2) is provided in Table 3. These data indicate that approximately 16% of all the nation's "river" reaches and 26% of the "river" miles receive at least one major discharge and that most of these are located in the eastern regions of the U.S. Table 4 provides a similar breakdown for just the POTWs, both those with indirect industrial inputs and those without. Unfortunately, this summary does not permit precise characterization of the particular type of aquatic system receiving the discharge i.e., buffered vs. unbuffered stream, coastal vs. estuarine system. However, certain gross generalizations are possible:

1) Point source dischargers are very densely clustered in the northeast where aquatic systems are poorly buffered and therefore more sensitive to impact.

2) Point sources are clustered near the mouths of rivers where they are likely to impact bays and estuaries.

3) POTWs are more evenly distributed across the country than industrial facilities; therefore impacts from POTW-related pollutants (BOD, TSS, chlorine, ammonia) may be of greater concern to the western regions than priority pollutants.

III. Ecological Effects

Predicted Impacts

An earlier issue paper (Attachment A) described the general ecological effects caused by the aforementioned stress agents, most of which are generated by point source dischargers to surface waters. In order to generically assess the potential for ecological impact from point sources after full implementation of BAT, a national dilution analysis was performed. The objective of the analysis was to: 1) predict instream concentrations for BOD and selected organic and inorganic pollutants on a reach-by-reach basis and 2) compare these projected concentrations with estimated effects criteria. Table 5 summarizes the results from the analysis based on 21,000 facilities (vs. a total of 39,000), for which sufficient data is available. Of the reaches receiving these point source discharges (14% of the nation's total), approximately 57% are projected to exceed one or more of the toxic "criteria" under low flow conditions (11% at mean flow). In addition, 29% of these reaches could be impacted by BOD loadings, even if nonpoint sources, probably the primary contributors of BOD, are completely ignored.

Direct Assessments

Preliminary analysis of 1986 State 305(b) reports provides data from direct observations of ambient water quality conditions. Forty States have provided information on approximately 22% of the nation's waters - primarily those that actually receive permitted discharges.

1. Rivers and streams: of the 328,000 miles assessed, 28% do not fully support designated uses; of these, 41% are impaired by point sources.
2. Lakes: 25% of the lake acres assessed do not fully support designated uses; of these, 15% are primarily impaired by point sources.
3. Estuaries: of the 2 million square miles assessed, 16% do not fully support designated uses; of these 49% are primarily impaired by point sources.
4. Coastal waters: only 1,500 miles of coastline were assessed (2 States); of these 11% were found impaired and 58% by point sources.

IV. Evaluation

As the single largest source of toxics (including chlorination products and ammonia) and a primary contributor of BOD, solids, nutrients, and thermal pollution, point dischargers pose an immediate and widespread threat to the nation's surface waters. Although pollutant loadings have been drastically reduced (relative to raw waste waters) with the promulgation of technology-based treatment requirements, significant impacts are still likely where dischargers are clustered and/or receiving systems provide limited dilution. This situation is most likely to occur near industrialized population centers. These are commonly located on major inland waterways or near coastal estuaries, but may also occur near smaller aquatic systems along important overland transportation routes or material resource centers. Thus the question is not so much "if" the impacts to aquatic systems are significant, but instead "where" will these impacts actually occur and how can the necessary water quality-based controls be put in place.

The source data and direct observations provided in this paper essentially confirm the likelihood of impacts predicted by the Cornell Workgroup (Figure 3). In addition, these data indicate that potential impacts associated with point source discharges may be of "high" magnitude on a regional as well as a local scale, at least for the eastern half of the country. Focus should be placed on point discharges as the major source of ecologically important toxics and second only to nonpoint sources with respect to BOD and solids loadings.

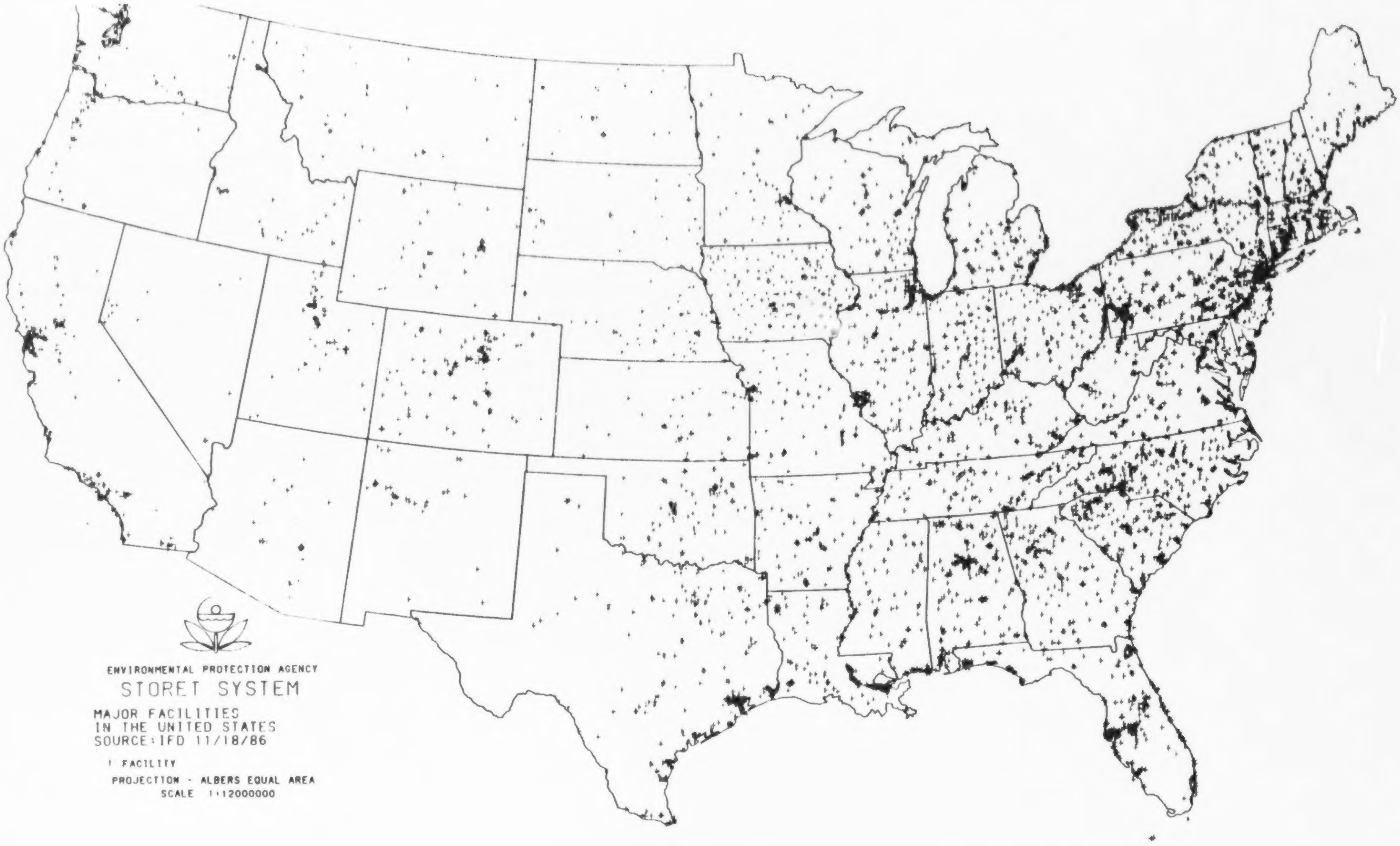
ENVIRONMENTAL PROTECTION AGENCY
STORET SYSTEM
MAJOR FACILITIES
IN THE UNITED STATES
SOURCE: IFD 11/18/86
1 FACILITY
PROJECTION - ALBERS EQUAL AREA
SCALE 1:12000000

FIGURE 1 GEOGRAPHIC DISTRIBUTION OF 7,000 MAJOR DISCHARGERS

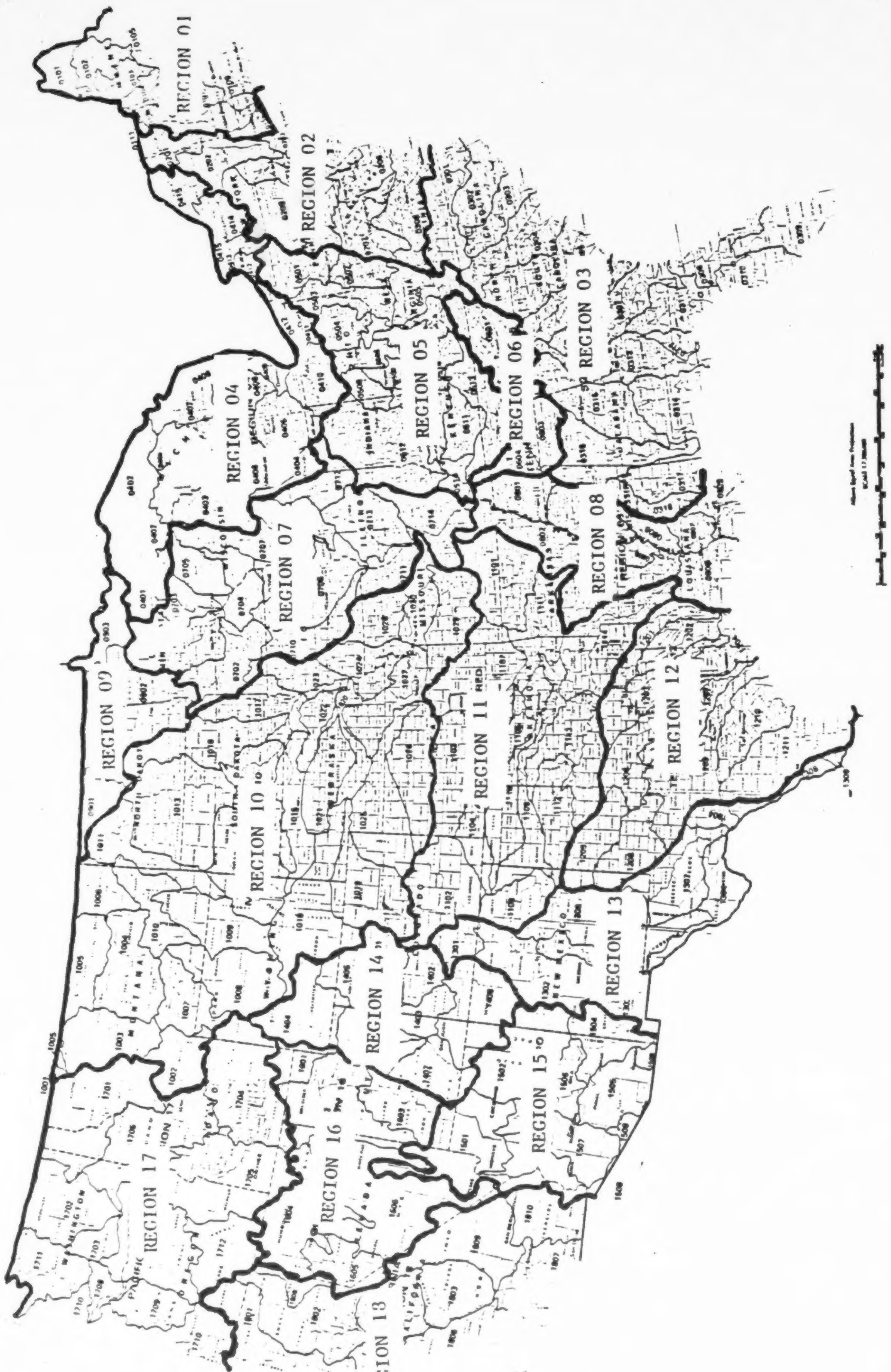
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FIGURE 2 HYDROLOGIC REGIONS OF THE UNITED STATES

FIGURE 3

ecosystems vs stress agents:	scale of effect			freshwater ecosystems				marine and estuarine ecosystems			wetland ecosystems			
	biosphere	regional	ecosystem	buffered lakes	unbuffered lakes	buffered streams	unbuffered streams	coastal	open ocean	estuaries	freshwater - isolated buffered	freshwater - isolated unbuffered	freshwater flowing	
water sources														
BOD			M	Mc b,p,o yr dec	Mc b,p,o yr dec	Mc b,p,o yr	Mc b,p,o yr	L	- -	Mc b,p,o yr dec	M yr	M yr	M yr	M yr
toxic organics		M	M	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	?	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b dec con
pesticides, herbicides		M	M	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	?	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b,p,o,b dec con 10	Mc b dec con
chlorination products		M	M	M? b,p,o dec con 10	M? b,p,o dec con 10	M? b,p,o dec con 10	M? b,p,o dec con 10	M? b,p,o dec con 10	?	M? b,p,o dec con 10	M? b,p,o dec con 10	M? b,p,o dec con 10	M? b,p,o dec con 10	M? dec con
toxic inorganics		M	M	Mc b,p,o,b dec con 12	Mc b,p,o,b dec con 12	Mc b,p,o,b dec con 12	Mc b,p,o,b dec con 12	L? dec con 12	?	M? b,p,o,b dec con 12	M? dec con	M? dec con	M? dec con	M? dec con
nutrients		M	M	Mc b,p,o yr dec 14	Mc b,p,o yr dec 14	Lc yr 14	Mc b,p,o yr 14	Mc b,p,o yr 14	- -	Mc b,p,o yr 14, 15	Mc yr dec 14	M? b,p,o yr dec 14	M? yr dec 14	Mc yr dec
microbes			- 16	- b 16	- b 16	- b 16	- b 16	- b 16	- b 16	- b 16	- b 16	- b 16	- b 16	-
turbidity			M	Lc b,p,o yr 17	Lc b,p,o yr 17	Mc b,p,o yr 18	Mc b,p,o yr 18	Mc b,p,o yr dec 19	- -	Mc b,p,o yr 20	L yr	L yr	L yr	Mc b yr
acids			M	Mc b,p,o dec	Mc b,p,o dec	Mc b,p,o dec	Mc b,p,o dec	- -	- -	L 21	Mc b,p,o dec	Mc b,p,o dec	Mc b,p,o dec	-
oil and petroleum products		M	M	M? b,p,o yr dec 23	M? b,p,o yr dec 23	M? b,p,o yr dec 23	M? b,p,o yr dec 23	M? b,p,o yr dec 23	?	M? b,p,o yr dec 23	- -	- -	M b,p,o dec	M b dec
thermal pollution			M	Mc b,p,o,b yr dec 22	Mc b,p,o,b yr dec 22	Mc b,p,o,b yr dec 22	Mc b,p,o,b yr dec 22	-	- -	Mc b,p,o,b yr dec 22	Mc b,p,o,b yr dec 22	Mc b,p,o,b yr dec 22	Mc b,p,o,b yr dec 22	Mc b yr dec
entrainment and impingement			?	? ,	? ,	? ,	? ,	-	-	? ,	-	-		-

TABLE 1

SUMMARY OF TOTAL POLLUTANT LOADINGS BY INDUSTRIAL CATEGORY NATIONWIDE

INDUSTRIAL INFORMATION			TOTAL SUSPENDED SOLIDS		BIOCHEMICAL OXYGEN DEMAND		PRIORITY ORGANIC POLLUTANTS		PRIORITY INORGANIC POLLUTANTS	
INDUSTRY NAME	NUMBER OF PLANTS	PROCESS FLOWS (1000 GPD)	AVG CONCENTRATION (ug/l)	TOTAL LOADING (lbs/d)	AVG CONCENTRATION (ug/l)	TOTAL LOADING (lbs/d)	AVG TTO CONCENTRATION (ug/l)	TOTAL TTO LOADING (lbs/d)	AVG TTI CONCENTRATION (ug/l)	TOTAL TTI LOADING (lbs/d)
ALUMINUM FORMING	42	7,258	12,000	727	--	--	5	0	1,039	63
BATTERY MANUFACTURING	15	111	12,000	11	--	--	--	--	1,705	2
COAL MINING	10,375	6,417,045	31,222	1,672,004	--	--	2	133	138	7,401
COIL COATING	36	1,132	12,000	113	--	--	39	0	926	7
COPPER FORMING	37	2,231	12,000	223	--	--	592	11	1,842	34
ELECTRICAL	84	12,806	12,000	1,282	--	--	703	75	1,418	152
FOUNDRIES	301	7,019	3,365	197	--	--	364	21	1,089	64
INORGANIC CHEMICALS	149	166,098	43,924	60,883	--	--	--	--	500	767
IRON & STEEL	738	1,497,651	10,859	135,470	--	--	21	262	204	2,551
LEATHER TANNING	17	4,160	56,000	1,944	33,800	1,173	168	6	1,930	67
METAL FINISHING	2,800	365,865	17,800	54,348	--	--	53	162	2,147	6,555
NONFERROUS METALS	112	8,671	2,750	199	--	--	48	3	1,696	132
NONFERROUS METALS FORMING	51	258	8,405	18	--	--	--	--	926	2
ORE MINING	515	1,359,000	8,451	95,845	--	--	--	--	1,112	12,616
ORGANICS/P&SF - $$	304	387,000	102,563	331,211	57,720	186,397	140	453	101	327
PESTICIDES	42	4.570	--	--	--	--	--	--	--	--
PETROLEUM REFINING	164	312,000	26,100	67,957	13,500	35.150	39	103	306	796
PHARMACEUTICALS	83	11,074	107,000	9,888	83,000	7,670	680	63	760	70
PLASTICS MOLDING & FORMING	810	88,476	4,866	3,593	3,527	2,604	168	124	129	95
PORCELAIN ENAMELING	28	1,784	12,000	179	--	--	--	--	2,077	31
POTWS - **	15,342	26,762,000	32,485	7,254,450	33,433	7,466,130	115	25,720	101	22,557
PULP & PAPER	355	3,746,444	28,445	889,338	17,327	541,732	103	3,355	261	8,166
TEXTILES	229	177,682	49,124	72,842	22,439	33,273	466	691	970	1,438
OTHER	6,602	--	--	--	--	--	--	--	--	--
TOTALS:	39,231			10,652,722		8,274,129		31,182		63.893

SOURCE: Industry Status Sheet Report (ISS).
NOTE: ISS flows and concentrations are based on applicable BPT, BCT, BAT, and secondary treatment regulations.
NOTE: Information unavailable for other industrial categories at this time.

NOTE: TTO - TOTAL TOXIC ORGANICS; TTI - TOTAL TOXIC INORGANICS

-- - INFORMATION UNAVAILABLE FROM ISS OR DEVELOPMENT DOCUMENTS
** - POTW plant flow and number information is from the 1984 Needs study.
Total priority pollutant loadings are average values of acclimated and unacclimated median loading values obtained from The Domestic Sewage Study.
Total TSS and BOD loadings are from the 1984 Needs study.
$$ - Based on ITD information (September 1986).

12/02/86

TABLE 2

SUMMARY OF TOTAL POLLUTANT LOADINGS
BY INDUSTRIAL CATEGORY FOR INDIRECT DISCHARGERS
NATIONWIDE

INDUSTRIAL INFORMATION			TOTAL SUSPENDED SOLIDS		BIOCHEMICAL OXYGEN DEMAND		PRIORITY ORGANIC POLLUTANTS		PRIORITY INORGANIC POLLUTANTS	
INDUSTRY NAME	NUMBER OF PLANTS	PROCESS FLOWS (1000 GPD)	AVG CONCENTRATION (ug/l)	TOTAL LOADING (lbs/d)	AVG CONCENTRATION (ug/l)	TOTAL LOADING (lbs/d)	AVG TTO CONCENTRATION (ug/l)	TOTAL TTO LOADING (lbs/d)	AVG TTI CONCENTRATION (ug/l)	TOTAL TTI LOADING (lbs/d)
ALUMINUM FORMING	64	3,633	12,000	364	--	--	4	0	1,056	32
BATTERY MANUFACTURING	126	441	11,967	44	--	--	--	--	2,566	9
COAL MINING	0	0	--	--	--	--	--	--	--	--
COIL COATING	119	5,253	12,000	526	--	--	116	5	1,507	66
COPPER FORMING	45	2,177	12,000	218	--	--	172	3	2,171	39
ELECTRICAL	265	32,119	28,324	7,402	--	--	628	166	2,096	540
FOUNDRIES	499	4422	3,609	135	--	--	517	19	1,383	52
INORGANIC CHEMICALS	38	5,017	195,593	8,189	--	--	--	--	2,063	86
IRON & STEEL	160	143,754	15,301	18,356	--	--	2,402	2,882	1,024	1,229
LEATHER TANNING	141	40,200	564,300	189,312	973,500	326,591	1,687	566	5,663	1,900
METAL FINISHING	7,500	800,631	17,800	118,931	--	--	53	354	2,161	14,439
NONFERROUS METALS	115	676	3,437	19	--	--	0	0	1,669	9
NONFERROUS METALS FORMING	151	434	6,376	23	--	--	--	--	1,241	4
ORE MINING	0	0	--	--	--	--	--	--	--	--
ORGANICS/P&SF - $$	366	94,000	442,000	346,698	1,022,000	801,641	68	53	98	77
PESTICIDES	39	3,454	--	--	--	--	--	--	--	--
PETROLEUM REFINING	47	61,000	92,100	46,885	133,200	67,807	6,575	3,347	1,566	797
PHARMACEUTICALS	388	54,125	686,000	309,862	2,036,000	919,648	680	307	760	343
PLASTICS MOLDING & FORMING	1,145	58,127	74,818	36,293	10,159	4,928	196	95	174	85
PORCELAIN ENAMELING	50	3,460	12,000	347	--	--	--	--	2,072	60
PULP & PAPER	261	709,579	430,444	2,548,938	291,280	1,724,858	2,831	16,764	438	2,595
TEXTILES	974	312,111	48,929	127,443	21,297	55,471	328	855	927	2,413
TOTALS:	12,493			3,759,985		3,900,944		25,416		24,775

SOURCE: Industry Status Sheet Report (ISS).
NOTE: ISS flows and concentrations are based on applicable pses regulations (current where pses was unavailable).
NOTE: Information unavailable for other industrial categories at this time.

NOTE: TTO - TOTAL TOXIC ORGANICS; TTI - TOTAL TOXIC INORGANICS

-- - INFORMATION UNAVAILABLE FROM ISS OR DEVELOPMENT DOCUMENTS
$$ - All information based on ITD information (September 1986), except TSS and BOD information which is based on ITD information (February 1983).

TABLE 3

SUMMARY OF REACHES
RECEIVING POINT SOURCE(DIRECT) DISCHARGES
BY HYDROLOGIC REGION
NATIONWIDE

14:32 TUESDAY, NOVEMBER 18, 1986

REGION	TOTAL NUMBER OF REACHES	TOTAL MILES	NUMBER OF REACHES INDUSTRIAL ONLY	INDUSTRIAL MILES ONLY	NUMBER OF REACHES POTW ONLY	POTW MILES ONLY	NUMBER OF REACHES IND. & POTW	IND. & POTW MILES
01	400	4,897	131	1,382	120	1,280	149	2,235
02	1,034	15,513	272	3,741	378	5,227	384	6,545
03	1,841	26,989	519	6,464	727	10,170	595	10,354
04	750	13,037	165	2,301	286	4,555	299	6,181
05	1,751	23,564	702	7,544	475	6,971	574	9,049
06	356	4,569	140	1,673	110	1,206	106	1,690
07	1,275	22,047	134	1,961	823	14,224	318	5,863
08	497	10,817	78	1,156	265	5,956	154	3,706
09	89	2,330	11	225	63	1,676	15	429
10	699	11,289	109	1,593	514	8,291	76	1,405
11	827	16,106	119	1,753	547	10,967	161	3,386
12	641	12,083	74	1,198	429	8,010	138	2,875
13	73	2,005	12	312	53	1,475	8	217
14	101	1,470	42	706	48	629	11	136
15	51	1,175	8	205	36	805	7	165
16	38	794	5	122	27	543	6	129
17	638	6,795	193	1,836	322	3,417	123	1,541
18	249	4,319	102	1,712	85	1,589	62	1,017
	======	=======	=====	======	=====	======	=====	======
	11,310	179,799	2,816	35,884	5,308	86,991	3,186	56,923

SOURCE: IFD and REACH FILE

NOTE: Sum of Entries May Not Equal Totals Due to Round-offs.

Total Number of Reaches in U.S. is 68,000.
Total Mileage of Reaches in U.S. is 700,000.

TABLE 4

SUMMARY OF POTWS RECEIVING INDUSTRIAL DISCHARGES
NATIONWIDE

14:22 TUESDAY, NOVEMBER 18, 1986

REGION	NUMBER OF POTWS	NUMBER OF REACHES	TOTAL MILES	TOTAL FLOW(MGD)	TOTAL NEEDS INDUSTRIAL FLOW(MGD)
01	175	130	1,616	931	222
02	347	258	4,006	3,358	593
03	498	406	6,088	1,277	414
04	272	219	4,091	3,190	780
05	291	262	4,989	1,589	341
06	82	74	1,034	202	70
07	390	321	5,857	2,492	525
08	86	66	1,505	207	74
09	13	12	376	25	4
10	123	115	1,968	608	141
11	121	106	2,149	432	80
12	119	97	2,182	677	107
13	11	9	339	87	7
14	7	7	57	11	1
15	5	5	94	65	8
16	9	8	125	71	12
17	69	64	763	439	108
18	87	68	1,247	1,517	342
	=====	=====	======	======	=====
	2,705	2,227	38,486	17,178	3,829

SUMMARY OF POTWS RECEIVING NO INDUSTRIAL DISCHARGES
NATIONWIDE

REGION	NUMBER OF POTWS	NUMBER OF REACHES	TOTAL MILES	TOTAL FLOW(MGD)	TOTAL NEEDS INDUSTRIAL FLOW(MGD)
01	242	186	2,666	682	.
02	1,237	644	10,386	2,694	.
03	1,844	1,084	17,416	1,411	.
04	791	475	9,164	6,995	.
05	1,868	926	14,109	32,132	.
06	234	166	2,297	99	.
07	1,538	971	17,545	564	.
08	830	397	9,291	262	.
09	95	71	1,920	46	.
10	678	515	8,520	337	.
11	940	647	13,183	315	.
12	1,174	522	10,097	1,081	.
13	76	56	1,457	35	.
14	72	55	736	29	.
15	58	41	942	162	.
16	37	29	604	130	.
17	522	411	4,689	611	.
18	167	104	1,559	1,318	.
	======	=====	=======	======	=
	12,403	7,300	126,982	48,903	0

[illegible] REACH FILE

1-11-16

Table 5

Summary of Projected Exceedances of Criteria or Toxic Effects Levels Along Stream Reaches at Two Flow Conditions with Inudstrial Direct Dischargers and POTWs

	LOW STREAM FLOW		MEAN STREAM FLOW	
	# of Reaches	Miles on Those Reaches	# of Reaches	Miles on Those Reaches
TOTAL IN U.S.	68,000	700,000	68,000	700,000
INDUSTRIAL (Only)	1,185	14,002	1,185	14,002
Inorganic Exceedances (Only)	578	7,547	131	1,907
Organic Exceedances (Only)	1	20	0	0
Inorganic & Organic Exceedances	45	509	6	29
BOD Exceedances	27	291	2	1
POTW (Only)	6,781	113,534	6,781	113,534
Inorganic Exceedances (Only)	2,617	45,330	598	9,436
Organic Exceedances (Only)	0	0	0	0
Inorganic & Organic Exceedances	1,135	21,239	38	649
BOD Exceedances	2,225	39,920	157	2,522
INDUSTRIAL & POTW	1,347	22,777	1,347	22,777
Inorganic Exceedances (Only)	668	11,773	268	4,637
Organic Exceedances (Only)	0	0	0	0
Inorganic & Organic Exceedances	220	3,933	11	186
BOD Exceedances	435	7,560	46	712
TOTALS				
Reaches Analyzed	9,313	150,310	9,313	150,310
Inorganic Exceedances (Only)	3,863	64,650	997	15,980
Organic Exceedances (Only)	1	20	0	0
Inorganic & Organic Exceedances	1,400	25,681	55	864
BOD Exceedances	2,687	47,771	205	3,235

Pollutants examined with criteria or toxic effects levels

Inorganics	Cadmium (1.1 ug/l) , Copper (12 ug/l), Mercury (.012 ug/l), Lead (3.2 ug/l), Zinc (47 ug/l) & Cyanide (5.2 ug/l)
Organics	Bis(2-ethylhexyl) phthalate (3 ug/l) , pentachlorophenol (PCP)(3.2 ug/l)
BOD	10 mg/l

Number of Facilities in Analysis 20,993

Introduction - The Perceived Problem

Roughly 65,000 permitted point sources (PCS) discharge approximately 6.4 trillion gallons of effluent (Renfroe, 1978) into the nation's surface waters every year even though many of the aquatic systems that receive these process wastes afford little dilution (40-60% of the stream reaches provide less than 10:1 dilution at low flow). And regulated discharges are not the only concern. There is mounting evidence that impacts caused by uncontrolled point sources (either non-compliant or illegal discharges) are as important as impacts caused by normal variations in effluent quality and stream flow (TSD, 1985). Combined sewer overflows (CSO's) also sporatically discharge large quantities of BOD, solids, and toxics that may severely impact certain areas.

A. Pollutants Discharged from Point Sources and Their General Effects

Pollutants of principal ecological concern can be grouped into three broad categories: oxygen-demanding materials (primarily organic nutrients) substances toxic to aquatic life, and other chemical/physical water physical water quality parameters (e.g., TSS).

1. Nutrients - Effects are typically characterized in terms of BOD, P, and N loading.

   Point sources, particularly POTWs, discharge organic and inorganic nutrients than can disrupt the natural trophic dynamics of an aquatic system. This metabolic imbalance will typically cause a shift in community structure from a relatively diverse biotic assemblage characterized by "clean water" species to one dominated by less desirable, "pollution tolerant" forms. In the extreme case, biochemical breakdown of excess organic material (either introduced or created from inorganic nutrients through biological production) can reduce dissolved oxygen to levels that are actually lethal to higher aquatic organisms. Because natural biochemical oxidation of organic nutrients is a relatively slow process, the various impacts of pollution are typically expressed at considerable distance from the point of discharge.

2. Toxic substances - Effects can be characterized by exceedance of criteria derived from an array of single-species bioassay tests.

   Toxicants can affect aquatic communities by differentially reducing or eliminating certain species populations. Overall productivity is inevitably reduced and alterations in competitive relationships are likely to cause shifts in community structure. The actual magnitude

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   Toxicants can affect aquatic communities by differentially reducing or eliminating certain species populations. Overall productivity is inevitably reduced and alterations in competitive relationships are likely to cause shifts in community structure. The actual magnitude and direction of such structural change is very difficult to predict because of the large number of toxic agents, the complexity of the mixtures actually discharged, and the wide variation in sensitivities among species. Toxic impacts are generally most severe in the immediate vicinity of discharge where concentrations are highest. Certain persistent toxicants may be transported considerable distances however before they are deposited and bioconcentrated into the food chain.

3. Conventional chemical/physical parameters - solids, pH, temperature.

   Suspended and settleable solids can affect aquatic life directly through mechanical, abrasive action (e.g., clogging gills, smothering eggs, and larvae) or indirectly by either altering habitats, (e.g. blanketing bottom substrates, spawing gravels etc.) or influencing water quality (reducing light penetration, sorbing cations, anions, organic compounds). Hydrogen ion concentrations (pH) also profoundly affect the physiology of aquatic organisms and the chemical/physical suitability of their environment; ambient pH values below 6.5 and above 9.0 are considered undesirable in freshwater (Quality Criteria for Water, 1986). Finally, temperature, one of the most important parameters affecting animal physiology and water chemistry, can cause ecological impacts when normal ambient levels are either chronically altered or abruptly changed.

B. Ecosystems Affected

   1. Marine Ecosystems - Because they are typically better buffered than freshwater systems (more dilution, greater hardness), marine systems are usually more resistant to stress. However, they are often slow to recover once damaged.

      a. Deep ocean - By virtue of its capacity to dilute foreign matter to inconsequential concentrations, the risk of damage from point source discharges was considered negligible.

      b. Coastal waters - Resistance to impact is relatively great due to high dilution and intense physical mixing. Biological communities of open coastlines are typically limited by organic nutrients; they can be drastically affected by any appreciable sewage inputs.

      c. Estuaries - Geographically more confined and enriched than open ocean or coastal zones, estuaries are biologically far more productive (per unit area). Many of the nation's largest population centers are located near the most important estuaries, thus threatening them with high concentrations of municipal and industrial wastes. Large POTW discharges may be located in such areas.

d. Tidal Wetlands - Wetlands function as filters of inorganic and organic material and as such serve to buffer adjacent aquatic systems. They are dominated by higher plant forms which provide both physical structure and functional stability. Because of the resistance of these higher plants to most toxics and excess nutrients, wetland systems are comparatively tolerant of chemical stress. But if the physical integrity is damaged (e.g., toxic contamination of the sediments or destruction of the dominant macrophytes) the system may never recover. Like estuaries, tidal wetlands are commonly located near population centers and are frequently impacted.

2. Freshwater Ecosytems - These systems can be broadly categorized as either lentic systems, standing waters such as lakes and wetlands, or lotic systems, flowing rivers and streams. "[Lakes]...are clearly less suitable repositories for effluents than are rivers which carry the offending matter away." (Hynes, 1971).

   a. Cold water streams - A large proportion of the nation's point source discharges are located on these low order streams. They are classically shallow, fast flowing, well oxygenated, and should support highly desirable sport fisheries. They are characterized by cobble/gravel riffles and runs interspersed with occasional pool areas. Biological communities are adapted to and limited by the slow release of nutrients from allochthonous organic matter i.e., gradual decomposition of resistant forest materials washed into the streams.

      These systems are likely to suffer major alterations in community structure and function when subjected to organic enrichment and/or DO depletion. Furthermore, these low-volume systems typically afford little dilution and are thus susceptible to impact from toxic as well as organic loadings. High current velocities and relatively inert bottom substrates, however, help prevent build up of persistent contaminants, thus promoting rapid/recovery from toxic stress. Biological assemblages have many r-selected species which can quickly repopulate defaunated areas and reestablish stable communities.

b. Warm water streams - These streams (rivers) occur at lower altitudes, have a lesser slope, a sluggish flow, and bottom substrates composed of fine silts, muds, and detritus. They generally have a much larger volume then cold water streams and thus greater assimilative capacity for discharged wastes. The biological communities are adapted to higher temperatures, lower DO levels, and greater organic loadings than cold water biota.

A large proportion of the nation's population and much of its industrial development has occurred along these waterways and they have always been subjected to massive inputs of nutrients and toxics. They are also more susceptible than fast-flowing streams to chronic contamination from sedimenting, persistent pollutants.

3. Lakes - Lakes vary tremendously in their size, origins, geology, and natural water quality. On a geologic time scale they are comparatively transitory, naturally becoming more "polluted" as nutrients leached from the surrounding drainage enter the lake. Nutrients are converted to organic material within the lake itself and deposited in bottom sediments. Eventually (>25,000 years), the lake basin actually fills with organic material and is transformed first to a wetland (bog) and finally to a terrestrial system.

Input of significant amounts of organic nutrients greatly accelerates the processes of lake eutrophication and destruction. Furthermore, lakes are particularly vulnerable to impacts from persistent toxicants because slow turnover rates cause them to act as despositional sinks for these pollutants.

4. Freshwater wetlands - These systems typically occur as marshes or swamps along high order streams and rivers where low relief provides a broad flood plain. Less frequently, wetlands represent the final stages of lake succession. Like tidal wetlands, these systems function as silt and nutrient filters, buffering water quality in the river while accomodating excess flow during flood periods. As transition systems, they are subject to inputs from both aquatic and terrestrial sources, are relatively resistant to stress, but are slow to recover particularly from physical alteration.

ECORISK NPS Summary #11

The major ecological risk from nonpoint sources is erosion. The primary pollutant is sediment which erodes from the surface of the land and is transported to streams, reservoirs, estuaries, and eventually to the ocean by the runoff from precipitation. Cropland is the chief source of sediment on a total mass basis. The latest figures indicate this source accounts for 38% of the total load annually. Pasture and range land contributes 25% while forests' share is 5%. Construction contributes 4% and mining 1%. Natural background accounts for 25%.

These sources contribute several pollutants in addition to sediment. Agriculture contributes excess nutrients, pesticides, and bacteria. Mining, runoff can be acidic, and from urban runoff we can expect heavy metals, and other toxic pollutants in addition to some sediment. Organic wastes are transported much the same way as sediment and have essentially the same adverse effects as organic wastes of domestic and industrial orgin. Thermal pollution is a concern from silviculture where removal of tree cover along stream banks exposes the water to the suns' rays. While the contribution of sediment from silviculture is low by comparision, it has a deleterious effect on spawning beds in upstream reaches. Fine silt can and does smother these beds rendering them useless. Other problems from excess sediment are silting of reservoirs, clogging of shipping channels, and the deposition of toxic pollutants which are attached to the sediments.

Problem #11

Nonpoint Sources and In-Place Pollutants

The work group modified the original problem definitions to fold a problem of aquatic in-place (sediment) pollutants into the problem of nonpoint sources. Because sediment contamination may result from either point or nonpoint sources, and is different in nature than a nonpoint source, it is simpler to discuss the two parts of problem #11 separately, as done in the following papers.

Narrative Description

Nonpoint Sources

To categorize nonpoint sources is not easy. As there are many. What will be discussed in the paper is a set of sources, generally accepted by those now directly involved in its control. This list is as follows: Agriculture, Silviculture, Construction, Urban, Resource Extraction, Hydromodification. It should be clear from this list that nonpoint sources occur everywhere. This is as it should be, for it rains everywhere and rain and runoff water are mostly responsible for the generation and transport of nonpoint source pollution to water bodies.

The land surface of the U.S. is about 2.2 billion acres these acres can be divided up by land use. In this way we may get a little perspective on the real extent of some of these rather large sources. About 500 million acres are related to agriculture, about 22 per cent of the U.S. then is devoted to this source. The nation's forests account for 33 per cent of the U.S. One can readily see the major sources. Urban for example covers 7 per cent of the land area, however, the populations are quite dense in comparison.

AGRICULTURE

The impact of agriculture on the nation's water resources is significant. Farmland in grass, pasture, and cropland plus farmsteads and roads total over 950 million acres of land area in the United States, and is scattered across the face of the land, intimately connecting with nearly all of the major water sources. Cropland represents about 413 million acres of farmland, pastureland accounts for an additional 133 million acres.

The major uses of water include industrial use, irrigation, public water supplies, navigation, recreation, and rural domestic uses. The quantity of water used for irrigation ranks second only to that for industrial use. Of the estimated 339 billion gallons of water consumed daily in the United States more than 35% is used for irrigation. The impact of the use of water for irrigation is limited mostly to the 17 western states where about 35 million acres of the total 39 million acres or irrigated land are situated.

The trend in agriculture is to employ modern technologies at ever increasing levels of complexity involving the use of fertilizers, pesticides, irrigation systems, and contained animal feedlots. A consequence of this trend will be the increased potential for water pollution both in the surface water and in the groundwater. Protecting water quality will become a major concern for agriculture.

Sources of Pollution from Agriculture

The pollutants resulting from agricultural discharges include sediments, salt loads, nutrients, pesticides, organic loads, and pathogens. Sediment resulting from soil erosion is regarded as the largest pollutant that affects water quality. Agricultural lands, particularly cropland, are large contributors of sediment. Holeman estimated the total erosion rate per year for the contiguous United States to be over 4 billion tons, of what about 2 billion tons washes into streams and 1 billion ton reaches tide waters. The national conservation needs inventory of the Soil Conservation Service estimated in 1971 that the total sediment yield from cropland per year was more than 1 billion ton. Thus, cropland is responsible for about 50% of the total sediment yield in inland waterways. Only a fourth of the total yield travels to the ocean. Sediment also carries with it significant quantities of plant nutrients, pesticides, organic and inorganic matter, pathogens, and other water pollutants.

About 2 billion tons of livestock wastes are produced annually in the United States. These fertilizers contain roughly 20% nitrogen, 5.2% phosphorus, and 8.8% potassium. Farmers use about 75% of the fertilizer consumed in the United States. The composition of plant nutrients in commercial fertilizers applied in different states varies considerably. For example, in Nebraska, the composition of commercial fertilizers consumed during 1970 averaged about 40% nitrogen, 5% phosphorus, and 3% potassium. For Iowa, these values were approximately 27% nitrogen, 7% phosphorus, and 11% potassium.

Some of these nutrients are transported, together with naturally occurring nutrient elements, to surface and groundwaters.

Irrigated agriculture involves leaching and transport of dissolved minerals in soils, and flushing the unwanted salts from the soil. About 60% of irrigation water is lost by evapotranspiration, while the remainder is returned by surface runoff and subsurface flow to surface waters and to groundwater storage. The return flows carry large quantities of minerals and degrade the water quality of the receiving streams.

Pesticides are designed to be lethal to target organisms, and many are toxic to nontarget organisms. Four major categories are important in agriculture: insecticides, fungicides, herbicides, and rodenticides. Our records show 660 million pounds of pesticides applied in the United States annually, about 70% was for farm use and the remaining 30% for public and governmental use.

The threat from pesticides is primarily due to their persistence in the aquatic environment, where fish and other food chain organisms accumulate pesticides and their metabolites or degradation products. This phenomenon of biological magnification appears to be especially significant with the fat-soluble pesticides.

Organic loads from agricultural activities include rural wastewaters, animal wastes, crop residues, and food processing wastes. When these substances are carried to a water body, they exert a high biochemical oxygen demand (BOD).

Agriculture wastes are a source of pathogens. Diseases may be transmitted through soil, water, or air when these wastes come in contact with plants and animals. Agricultural losses caused by infectious agents of livestock and poultry have been substantial. Wadleigh has summarized the cases of diseases transmitted by infectious agents and allergens affecting plants and animals from agricultural wastes.

Silviculture

Over one-third of the U.S. is covered with forests. Approximately 67% of the forests are classified as commercial forests, totaling 500 million acres, of which approximately 67 million acres are in private industrial ownership, 100 million acres are in public ownership, and the rest in private, non-industrial ownerships. Depending on natural and land use characteristics, these lands may produce substantial quantities of pollutants to surface and underground waters.

An established, well managed forest can be remarkably resistant to emission of pollutants to the aquatic environment. Incident rainfall is deprived of most of its erosive force by the tree cover, and rates of infiltration through ground cover and into subsurface soils are given often high enough that intense rainfall can be accommodated without runoff and the accompanying cary-off of silt by erosion. Such a forest has the attributes popularly decreed to be necessary and desirable, as well as technically and economically sound. Many forests do indeed possess such attributes, and are at the same time useful, productive entities. Productivity can be maintained over the long term with assistance from man, which necessarily includes harvest of trees. A silvicultural cycle includes a relatively long period of growth which can be essentially free of pollutional output, and a relatively short period of harvest and reforestation, which, as a result of disturbance, can be a time of high pollutional output.

The principal aspect of silviculture we are concerned with here is timber harvesting. The nations' forests are basically the nations' watersheds, where water first begins its journey to oceans. Water in the forests is usually of high quality and risk is small. Sediment and nutrients can be a problem from harvesting if it is done improperly. One aspect that has received attention in the past four or five years, is the resultant destruction of of fish habitat from sediment deposition. Fine-grained Sediment, settles in gravels of upstream reaches, below where timber harvesting is being practiced, usually in the mountain where coldwater fish and annadramous fish spawn. The result is reduction or destruction of in spawing sites.

Disturbances to the forest come from nature as well as from man. Disease, insects, windstorms, droughts, and fires can devastate a forest, and degrade it to a polluting condition. Silvicultural activities, which are generally concerned with timber production, with prevention of natural devastation, and with restoration to a state of health and productivity, consist of harvesting, reforestation, growth promotion, disease prevention, fire fighting and fire prevention.

The principal sources of pollution from forests thus are disturbances caused by man. The major types of pollutants from forestlands are sediment, organic matter, applied forest chemicals (pesticides, fertilizers, fire retardants), plant nutrients, and pathogens. Thermal effects on streams from solar radiation associated with the reduction of shade from streamside vegetation are, in some cases, pollutional.

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Urban

We probably know more about this source than all of the others. Runoff from urban areas is a result of rainfall washing the streets, steel mills, parking lots, etc. The effects of the stress agents are primarily to violate water quality criteria. This is the most frequently encountered problem. In certain causes the runoff will necessitate the closing of shell fish beds due to the high bacteria counts in urban runoff. Copper is a stress agent that is lethal to lower forms of aquatic life at very low concentrations. As a result our criteria is quite low and copper is ubiquitous in urban runoff and violations occur most of the time. There is no evidence, however, of fish (large fish) being killed from separate storm sewer discharges.

One problem from separate storm sewers is that the are not always entirely separate. There is a wide-spread unspoken problem with illegal connections. These are sanitary connections, industrial connections, and commerical connections, that for one reason or another have been connected to the storm drains instead of to the sanitary lines. The result is continous discharge of untreated waste. The cost to correct this problem is so high that it will probably be the last thing done to clean up the environment. Example of cities that have this problem are Baltimore, New Orleans, and Fort Worth. There are many others.

Construction

The accelerated rise in the U.S. population through the year 2000 will require the daily development of about 4,000 acres of land to accommodate the expanded requirements for new housing and related services, transportation, utilities, communications, and sewer and wastewater treatment networks--all of which are construction oriented. Land areas sufficient to accomodate these new operations must be found without limiting those land and water resources needed to produce the food supplies essential to the sustenance of increased numbers of plants, animals, and man. At the present time, more than two-thirds of the U.S. population is located in urbanized areas covering 7% of the land area.

This source includes urban, rural, and other areas of construction. The primary concern is site runoff and the resulting excess sediment loss. This is another example of a land disturbance similar to silviculture and agriculture. The difference is the length of time associated with the land exposed to the elements. The loads are unusually high but do not last long, causing a short term insult to the enivronment compared to ag or silvicultural sources.

Emphasis must be placed on the fact that environmental impacts of construction must be assessed on a site-by-site basis. Construction activity refers to major jobs, characterized in part as heavy (as in damsites and other excavations), highway, housing developments, transmission and pipelines, dredging, and demolition operations--whether done in an urban or rural environment. Construction practice refers to timber clearing, grubbing, and topsoil stripping; rough grading, concrete, asphalt and other facility operations; waste disposal; soil stabilization, fertilization, and revegetation; traffic control; pest control, and site restoration following construction. This term includes all job operations that generate various types of water jpollutants by spillage, erosion, sedimentation, and stormwate runoff.

Hydromodification

This source involves channelization, dam construction, flood control, and other water detention and/or drainage-related structures or operations. This work is generally site specific and sometimes short term in nature, however, in the use of channel dredging it is normally periodic in nature. As cities grow, and highways grow rivers, in particular are affected by the construction of bridge piers and abutments. There has been much channelization for drainage control in urban areas and for agriculture. The primary effect is habitat alteration which often causes serious problems.

In addition, when flow regimes of streams are altered, such as in dam building, water flow regimes are changed remarkably which results in sedimentation problems in the reservoirs and downstream. Hydromod differs from construction as it relates only to water bodies.

Resource Extraction

For purpose of this assessment, energy resources from extraction were not considered as this is being covered under a separate element. Mining activities in the U.S. have affected approximately 20 million acres of land according to estimates by the U.S. Department of the Interior. By the year 2000 the Department estimates that 30 milion acres will be affected by mining operations.

While the land area presently affected by mining represents only about 1 per cent of the U.S., the effects of mining upon water quality and quanity are spread over large regions. The effects of mining include pollution of water supplies with acid mine drainage, heavy metals, toxic substances, and sediment.

Nonpoint source pollution from mining operations arises because the hydrology of surface and subsurface waters is altered when the earths' crust is disturbed to gain access to minerals and minerals are exposed to oxidation. The quality of this water very often deteriorates, and the quantity is redistributed as a result of the mining operations. Water quality deteriorates when water supplies are contaminated with soluble products present in or generated from mining wastes. Water quantity is affected because natural drainage patterns for surface and subsurface waters are altered.

Completeness of Information	Water Quality		Effects		Areal Extent				Other			
	LOADS	Concentrations	Exposure	Response	River Miles	Lake Acres	Estuaries	Acres	Models	Criteria	Controls	Demonstrations
Agriculture	1	2	3	3	2	2	3	1	2	3	3	3
Silviculture	2	3	3	4	3	3	3	1	3	3	3	3
Urban	1	1	2	2	2	2	2	1	1	3	2	2
Resource Extraction	2	3	3	4	3	3	4	2	3	3	3	3
Construction	2	3	3	4	2	2	3	2	2	3	2	2
Hydromodification	3	4	4	4	2	2	2	3	4	3	3	3

1. OK we have sufficient information
2. We have some but can use more
3. We need more
4. We have some real need

Completeness

There is much information on nonpoint sources however, it is not all of the useful type. There are whole areas where there is a real need for information. There are areas of need we will never fill.

The different types of information are myriad and as such are probably best discussed in tabular form. The following chart lists the various nonpoint source categories and the different types of information that we feel we need to control nonpoint source pollution.

AGRICULTURE

	Areal Extent				Stress agents 1000's tons/yr							
					NUTRIENTS							
SOURCES:	Stream Miles X 1000	Lake Acres X 1000	Estuary X 1000 mi.^{2}	Acres X 1,000,000	Nitrogen	Phosphorus	Sediment ***	Pesticides X 106 lbs.	Microbes	Physical Habitat Alteration		
CROPLAND				413	12,300	5,700	3 bill.	600				
RANGELAND												
PASTURELAND				133			49,000					
Irrigated Cropland												
Livestock Fac.					7,000*	1,700*						
Agriculture Total												
305(b) Report ASIWPCA 1985**	97	3,700					X					
	31	900						X				
	40	825							X			
	19	127			X	X				X		
	54	5,400			X	X						

* Note: Nutrients derived from manure. Source: "Report to Congress: Nonpoint Source Pollution in the the U.S.". 1984

** Note: ASIWPCA Report prepared by the States at EPA's request and funding. Mileage and acreage if from those streams and lakes assessed. Many miles and lake acres were not assessed.

*** Note: Numbers from EPA-430/9-73-014-1073, "METHODS FOR IDENTIFYING AND EVALUATING NONPOINT SOURCES OF POLLUTANTS".

**** Note: ASIWPCA Report data indicates areal extent effected and the X indicates stress agent.

SILVICULTURE

	Areal Extent				Stress agents 1000's tons/yr							
SOURCES:	Stream Miles X 1000	Lake Acres X 1000	Estuary X 1000 mi.^{2}	Acres X 1,000,000	Nitrogen *	Phosphorus *	Sediment	Pesticides X 106 lbs. *				NOTE
Natural Forestry Area				488	NEG	NEG	18,300	NEG				.0375 ton/a
Timber Harvest/yr				3	NEG	NEG	56,250	NEG				18.75 ton/y
ASWIPCA	34						X					

* Note: NEG - negligible amount

*** Note: ASIWPCA report data indicates areal extent effected and the X indicates stress agent.

URBAN

SOURCES:	Areal Extent**				Stress agents 1000's tons/yr *							
	Stream Miles X 1000	Lake Acres X 1000	Estuary X 1000 mi.2	Acres X 1000	Nitrogen	Phosphorus	Sediment	Pesticides X 106 lbs.	Microbes	Toxic Substances		
Separate Storm sewer discharge	68.25	6,682		16,000	185	37	18,000	.33				
		3,255			X	X						
	48	280							X			
	15	952								X		

* Note: Source: Resources For the Future "Nonpoint Pollution: Are Cropland Controls the Answer?" 10/1/85

** Note: Source: ASIWPCA Report, "The State's Nonpoint Source Assessment, 1985"

*** Note: ASIWPCA Report data indicates areal extent effected and the X indicates stress agent.

CONSTRUCTION AND HYDROGRAPHIC MODIFICATION

	Areal Extent				Stress agents 1000's tons/yr							
SOURCES:	Stream Miles X 1000	Lake Acres X 1000	Estuary X 1000 mi.^{2}	Acres X 1000	Nitrogen	Phosphorus	Sediment X 1000	Pesticides X 106 lbs.	Physical Habitat Alteration			
Construction	3.3	324										
Hydromod. fr	6.6	1053					X		X			
ASIWPCA 1985												
Construction												
Highways							15*					
Urban							15*					
Hydromod dredged												
annually	19		1									
Dams**	75											
Channelization**	11											
Flood control**	8											

* Note: Source EPA-600/2-75-007, 4/75 "IMPACT OF HYDROLOGIC MODIFICATIONS ON WATER QUALITY".

** Note: Source "Report to Congress: Nonpoint Source Pollution in the U.S.". January 1984

*** Note: ASIWPCA Report data indicates areal extent effected and the X indicates stress agent.

RESOURCE EXTRACTION

	Areal Extent				Stress agents 1000's tons/yr							
SOURCES:	Stream Miles X 1000	Lake Acres X 1000	Estuary X 1000 mi.^{2}	Acres X 1000	Nitrogen	Phosphorus	Sediment	Pesticides X 106 lbs.	Waste Generation (millions of tons 1982) *	Toxic Substances	Physical Habitat Alteration	
Metals												
Mine Waste									408			
Tailings									307			
Leaching Wastes									211			
Nonmetals												
Mine Waste									298			
Tailings									111			
Leaching Waste									---			
All Types	10									X		
	17										X	

* Note: Source is "Report to Congress: Nonpoint Source Pollution in the U.S.". January 1984

Exposure

The exposure of receiving water to nonpoint source pollution is a direct result of rainfall and the corresponding runoff. Therefore the exposures are dependent on the runoff. This makes it easy to understand that exposures of nonpoint source are of short duration, on the order of hours, and infrequent, about once every three days. We have the necessary data on rainfall to determine the long term frequency and duration as well as volume of events at 6000 sites nationwide.

To date, only urban runoff has been analyzed using the rainfall, runoff statistics. For other sources we must rely on substitute information. The preceeding section, of this report, on sources lists areal extent and by use of check marks indicate, to some degree, the exposure of source such as agriculture, construction, hydromod, etc.

Because of relatively short duration of storm events, there is a lack of sufficient time for the washed pollutants to do serious damage. In addition, the events are infrequent enough so as to let the effected stream recover before it rains again. While this is true for urban runoff, it is not clear that this also applies to agriculture.

For as to be better able to assess exposure resulting from periodic storm events, we will need new methodologies, more data on close-response for more organisms. We have made an initial attempt at this for urban runoff. We found that current water quality criteria was not sufficient for our purpose. We developed our own and were thus able to develop a better understanding of the runoff/receiving water effect phenomenon.

The following graph was developed from extensive data collection and analysis and the use of special water quality criteria developed as part of the NURP program. The graph allows us to present, on sheets of paper, the effects of urban runoff in terms of frequency of violation of a criteria, frequency of biological effects, and how much control may be needed to meet a given criteria.

RECEIVING WATER QUALITY EFFECTS

General

A number of individual NURP projects examined the site-specific impacts of urban runoff on water quality for a variety of beneficial uses and receiving water types. These results provide important information on the extent to which urban runoff constitutes a "problem" as well as "ground truth" measurements against which more generalized techniques can be compared. Methodologies employed in these local studies vary and are described in the individual project reports. Relevant site-specific project results are cited in Chapter 9.

Receiving water impact analyses cannot be readily generalized because there is a high degree of site-specificity to the important factors. The type of beneficial use dictates the pollutants which are of principal concern; the type of water body (e.g., stream, lake, estuary) determines how receiving water quality responds to loads; and physical characteristics (e.g., size, geometry, flows) have a major influence on the magnitude of response to a particular load.

Despite the inherent limitations of a set of generalized receiving water impact analyses, a screening level analysis was considered a necessary element for a nationwide assessment of the general significance of urban runoff in terms of water quality problems, especially adverse effects on beneficial uses. Accordingly, a set of analysis methodologies were adopted and utilized as screening techniques for characterizing water quality effects of urban runoff loads on receiving water bodies. A key requirement was to delineate the severity of water quality problems by quantifying the magnitude, and in the case of intermittent loads, the frequency of occurrence of water quality impacts of significance. These procedures are identified and described briefly below. Significant technical aspects are detailed further in the supplementary NURP report which addresses the receiving water impact analysis methodology.

It was not possible to perform a "National Assessment" in the usual sense of the term. NURP has determined that it is not realistic (if the basis is effect on beneficial use of a water body) to estimate the total number of water quality problem situations in the nation which result from urban stormwater runoff or the cost of control which would ultimately result. The available analysis methods do permit an assessment of a different kind. NURP applied the analysis procedures as a screening type analysis to define the conditions under which problems of different types are likely or unlikely to occur. From the results of these screening analyses, NURP has drawn inferences and made general statements (Chapters 7 and 9) on the significance of urban runoff. Where it has been possible or practical to do so, these general screening analyses were applied to local situations which exist within certain of the individual NURP projects. Comparisons were made between specific water quality effects or broader conclusions relative to problems derived from both local analysis and general screening methods.

Time Scales of Water Quality Impacts

There are three types of water quality impacts associated with urban runoff. The first type is characterized by rapid, short-term changes in water quality during and shortly after storm events. Examples of this water quality impact include periodic dissolved oxygen depressions due to oxidation of contaminants, or short-term increases in the receiving water concentrations of one or more toxic contaminants. These short-term effects are believed to be an important concern and were the prime focus of the NURP analysis.

Long-term water quality impacts, on the other hand, may be caused by contaminants associated with suspended solids that settle in receiving waters and by nutrients which enter receiving water systems with long retention times. In both instances, long-term water quality impacts are caused by increased residence times of pollutants in receiving waters. Other examples of the long-term water quality impacts include depressed dissolved oxygen caused by the oxidation of organics in bottom sediments, biological accumulation of toxics as a result of up-take by organisms in the food chain, and increased lake entrophication as a result of the recycling of nutrients contributed by urban runoff discharges. The long-term water quality impacts of urban runoff are manifested during critical periods normally considered in point source pollution studies, such as summer, low stream flow conditions, and/or during sensitive life cycle stages of organisms. Since long-term water quality impacts occur during normal critical periods, it is necessary to distinguish between the relative contribution of urban runoff and the contribution from other sources, such as treatment plant discharges and other nonpoint sources. A site-specific analysis is required to determine the impact of various types of pollutants during critical periods, and this aspect of urban runoff effects was not addressed in detail in NURP.

A third type of receiving water impact is related to the quantity or physical aspects of flow and includes short-term water quality effects caused by scour and resuspension of pollutants previously deposited in the sediments. This category of impact was not addressed by NURP, in general, although one project provides some information.

As indicated previously, the first type of change in water quality associated with discharges from urban runoff is characterized by short-term degradation during and shortly after storm events. The rainfall process is highly variable in both time and space. The intensity of rainfall at a location can vary from minute to minute and from location to location. Phenomena which are driven by rainfall such as urban runoff and associated pollutant loadings are at least as variable. Short term measurements, on a time scale of minutes, to define rainfall, the runoff flow hydrograph, and concentrations of contaminants (pollutographs) feasibly can be taken at only a rather limited number of locations. These measurements have usually been employed in an attempt to refine or calibrate calculation procedures for estimating runoff flows and loads. Most urban areas contain a network of drainage systems which collect and discharge urban runoff into one or more receiving water bodies. Since the rainfall, runoff, and pollutant loads vary in both time and space, it is impossible to determine by calculation or measurement the very short time scale (minute-to-minute) changes in water quality of a receiving water and assign the changes to specific sources of runoff. Although very short duration exposures (on the order of minutes) to very high concentrations of toxics can produce environmental damage (mortality or sublethal effects) to aquatic organisms, it is likely that exposures on the order of hours have the highest possibility of causing adverse environmental impacts. This results, in part, from the smoothing obtained by mixing numerous sources which have high frequency (short-term) variability.

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In view of the above discussion, the time scale used by NURP for analysis of short-term receiving water impacts is the rainfall event time scale which is on the order of hours. To represent the average concentration of pollutants in urban runoff produced during such an event, NURP used the event mean concentration.

Criteria/Standards and Beneficial Use Effects

As discussed in previous chapters, three definitions have been adopted to assess receiving water problems associated with urban runoff; (1) impairment or denial of beneficial use, (2) violation of numerical criteria/standards, and (3) local perception of a problem. The procedures and methods employed in the NURP assessment focus on the first two problem definitions. A framework for identifying target receiving water concentrations associated with the criteria standards and beneficial use problems are provided below. The third problem type, local perception of a problem and degree of concern cannot be addressed by these quantitative procedures.

The analysis methods employed make it possible to project water quality effects caused by intermittent, short-term urban runoff discharges. Where appropriate, these effects are expressed in terms of the frequency at which a pollutant concentration in the water body is equalled or exceeded. However, if the basis for determining the significance of such water quality impacts (and hence the need for control) is taken to be the effect such receiving water concentrations have on the impairment or denial of a specific beneficial use, then it is necessary to go one step further. A basis is required for judging the degree to which a particular water quality impact constitutes an impairment of a beneficial use. With intermittent pollutant discharges, effects are variable and are best expressed in terms of a probability distribution from which estimates can be made of the frequency with which effects of various magnitude occur.

There is a rather broad consensus that existing water quality criteria, and water uses based on such criteria, are most relevant when considered in terms of continuous exposures (ambient conditions). Even where continuous discharges are involved, there has been discussion and debate as to whether a particular criterion should be interpreted as some appropriate "average" condition or a "never-to-exceed" limit. The basic issue is whether the more liberal interpretation will provide acceptable protection to the beneficial use for which the criterion in question has been developed. The only reason such distinctions become an issue is because the practical feasibility or relative economics, or both, are sufficiently different that one is encouraged to question whether the more restrictive interpretation is overly (or even excessively) conservative in terms of providing protection for the associated beneficial use.

The issue (i.e., whether traditional ambient criteria are excessively conservative measures of conditions which provide reasonable assurances of protection for a beneficial use when exceeded only intermittently) is particularly appropriate in the case of urban storm runoff. Analysis of rainfall records for a wide distribution of locations in the nation indicates that, even in the wetter parts of the country, urban runoff events occur only about 10 percent of the time. There are regional and seasonal differences, but typical values for annual average storm characteristics in the eastern half of the United States are:

	Average (Hours)	Median (Hours)	90th Percentile (Hours)
Storm Duration	6	4.5	15
Interval Between Storm Mid-Points	80	60	200

These estimates are based on results from an analysis of long-term rainfall records for 40 cities throughout the country. Median and 90th percentile values are derived from data mean and variance based on a gamma distribution, which has been shown to characterize the underlying distribution of storm event parameters quite well.

In the semi-arid regions of the western half of the country, average storm durations tend to be comparable to the above, but average intervals between successive storms increase substantially (two to four fold) and are highly seasonal. With urban storm runoff, therefore, one is dealing with pollutant discharges which occur over a period of a few hours every several days or more or after long dry periods. In advective rivers and streams, the water mass influenced by urban runoff tends to move downstream in relatively discrete pulses. Because of the variability in the magnitude of the pollutant loads from different storm events, only a small percentage of these pulses have high pollutant concentrations.

There are currently no formal "wet weather" criteria and, thus, no generally accepted way intermittent exposures having time scale characteristics typical of urban runoff can be related to use impairment. In the belief that it would be inappropriate to ignore such considerations in a general evaluation of urban runoff, NURP has developed estimates for concentration levels which result in adverse impacts on beneficial use when exposures occur intermittently at intervals/durations typical of urban runoff. These "effects levels" were used to interpret the significance of the variable, intermittent water quality impacts of urban runoff. It should be understood that these effects levels do not represent any formal position taken by EPA, but are simply the most reasonable yardsticks available to meet the immediate needs of the evaluation of urban runoff. As used in the screening analysis procedures, alternative values for "effects levels" may be readily substituted when either more accurate estimates can be made, or more (or less) conservative approaches are indicated in view of the importance of a particular water body or beneficial use.

Table 5-1 summarizes information on water quality criteria for a number of contaminants routinely found in urban storm runoff. The data presented include:

- Water quality criteria for substances on EPA's priority pollutant list (45 FR No. 79318, 11/28/80). These criteria provide

TABLE 5-1. SUMMARY OF RECEIVING WATER TARGET CONCENTRATIONS USED IN SCREENING ANALYSIS - TOXIC SUBSTANCES

(ALL CONCENTRATIONS IN MICROGRAMS/LITER, μg/ℓ)

Contaminant	Water Hardness mg/l (as Ca CO_3)	Freshwater Aquatic Life		Saltwater Aquatic Life		Human Ingestion	Estimated Effect Level For Intermittent Exposure	
		24 Hour	Max	24 Hour	Max	(1)	Thresh-hold	Significant Mortality
Copper	50	5.6	12	4.0	23	NP	20	50 - 90
	100	5.6	22	4.0	23		35	90 - 150
	200	5.6	42	4.0	23		80	120 - 350
	300	5.6	62	4.0	23		115	265 - 500
Zinc	50	47	180	58	170	NP	380	870 - 3,200
	100	47	321	58	170		680	1,550 - 4,500
	200	47	520	58	170		1,200	2,750 - 8,000
	300	47	800	58	170		1,700	3,850 - 11,000
Lead	50	0.75	74				150	350 - 3,200
	100	3.8	172	(25)	(670)	50.0	360	820 - 7,500
	200	12.5	400				850	1,950 - 17,850
	300	50.0	660	(C)	(A)		1,400	3,100 - 29,000
Chrome (+3)	50		2,200					
	100	(44)	4,700	N.P.	(10,300)			
	300	(C)	15,000		(A)	170.00	8,650	
Chrome (+6)	-	0.29	21.0	18	1260	50.0		
Cadmium	50	0.01	1.5				3	7 - 160
	100	0.02	3.0	4.5	59.0	10	6.6	15 - 350
	300	0.08	9.6				20	45 - 1,070
Nickel	50	56	1,090					
	100	96	1,800	7.1	140.0	13.4		
	300	220	4,250					

NOTES:

- NF = No criteria proposed.
- Some toxic criteria are related to Total Hardness of receiving water. Where this applies, several values are shown. Other values may be calculated from equations presented in EPA's Criteria Document (Federal Register, 45,231, November 28, 1980). Where a single value is shown, water hardness does not influence toxic criteria.
- Concentration values shown within parentheses ( ) are not formal criteria values. They reflect either chronic (C) or acute (A) toxicity concentrations which the EPA toxic criteria document indicated have been observed. Values of this type were reported where the data base was insufficient (according to the formally adopted guidelines which were used in developing the criteria) for EPA to develop 24 hour and Max values.
- Note (1): The "Human Ingestion" criteria developed by the EPA Toxic Criteria documents are indicated to relate to ambient receiving water quality. The Drinking Water Criteria relate to finished water quality at the point of delivery for consumption.
- Estimated Effects levels reflect estimates of the concentration levels which would impair beneficial uses under the kind of exposure conditions which would be produced by Urban Runoff. They are an estimate of the relationship between continuous exposure and intermittent, short duration exposures (several hours once every several days). Threshold concentrations are those estimated to cause mortality of the most sensitive individual of the most sensitive species.

  Significant Mortality concentrations are shown as a range which reflects 50 percent of the most sensitive species and mortality of the most sensitive individual of the 25th percentile species sensitivity.

an extensive set of numerical values derived from bioassay studies.

- Estimates of "effects levels" which are suggested by NURP analysis to be relevant for the intermittent exposures characteristic of urban runoff.

By incorporating the numerical values for EPA's ambient water quality criteria and the concentration levels suggested by NURP for intermittent effects in the same table (or on the same graph in Chapter 7), a convenient, concise comparison is provided of the practical implications of applying one or the other as the yardstick for judging the protection or impairment of water use. The two sets of numerical values thus provide measures for two of the three options for defining a problem: violation of criteria or actual impairment of a beneficial use.

Comparison of the pollutant concentrations in urban runoff showing the frequency and magnitude of exceedance of ambient criteria and intermittent effects levels provides a qualitative sense of the control requirements (and implications regarding costs) attendant on the adoption of either problem definition as the operative one.

Rivers and Streams

The approach adopted to quantify the water quality effects of urban runoff for rivers and streams focuses on the inherent variability of the runoff process. What occurs during an individual storm event is considered secondary to the overall effect of a continuous spectrum of storms from very small to very large. Of basic concern is the probability of occurrence of water quality effects of some relevant magnitude.

To consider the intermittent and variable nature of urban runoff, a stochastic approach was adopted. The method involves a direct calculation of receiving water quality statistics using the statistical properties of the urban runoff quality and other relevant variables. The approach uses a relatively simple model of the physical behavior of the stream or river (as compared to many of the deterministic simulation models). The results are therefore an approximation, but appropriate as a screening tool.

The theoretical basis of the technique is quite powerful as it permits the stochastic nature of runoff process to be explicitly considered. Application is relatively straightforward, and the procedure is relevant to a wide variety of cases. These attributes are particularly advantageous given the national scope of the NURP assessment. The details of the stochastic method are summarized and presented below.

Figure 5-2 contains an idealized representation of urban runoff discharges entering a stream. The discharges usually enter the stream at several locations but are considered here to be adequately represented by an equivalent discharge flow which enters the system at a single point.

Receiving water concentration (CO) is the resulting concentration after complete mixing of the runoff and stream flows and is interpreted as the mean

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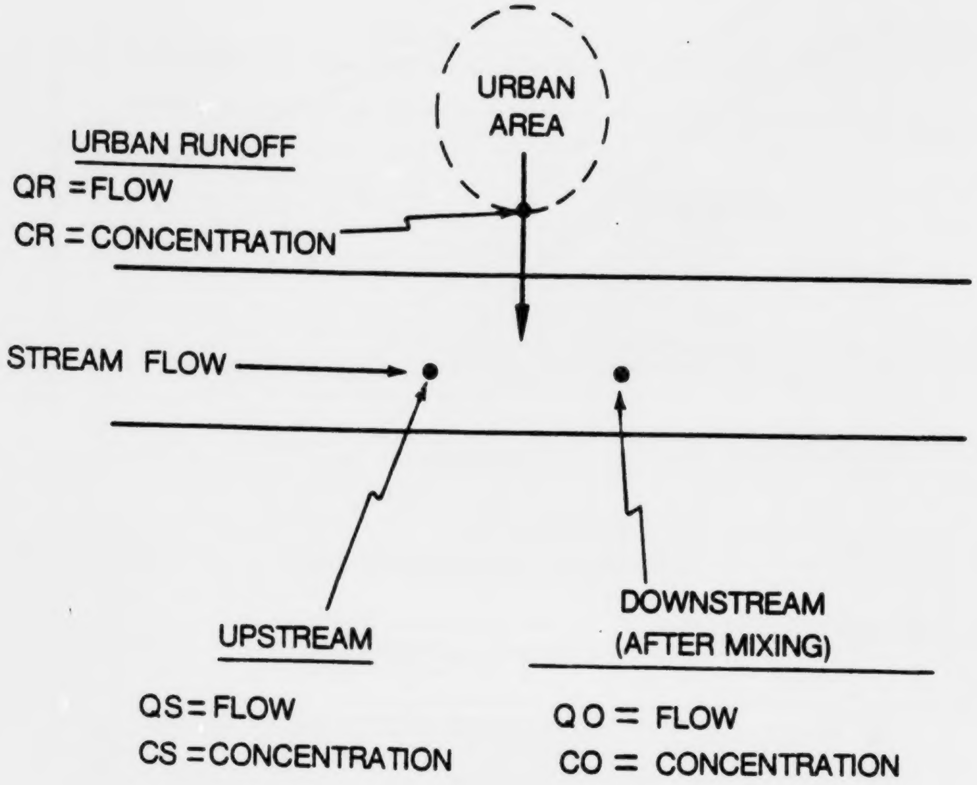
URBAN AREA
URBAN RUNOFF
QR = FLOW
CR = CONCENTRATION
STREAM FLOW
UPSTREAM
QS = FLOW
CS = CONCENTRATION
DOWNSTREAM (AFTER MIXING)
QO = FLOW
CO = CONCENTRATION

Figure 5-2. Idealized Representation of Urban Runoff Discharges Entering a Stream

stream concentration just downstream of all of the discharges as shown in Figure 5-2. The four input variables considered are:

- Urban runoff flow (QR)
- Urban runoff concentration (CR)
- Stream flow (QS)
- Stream concentration (CS)

Each is considered to be a stochastic random variable, which together combine to determine downstream flow and concentration. In addition, all variables are assumed to be independent, except urban runoff flow and streamflow where correlation effects can be incorporated as warranted.

6

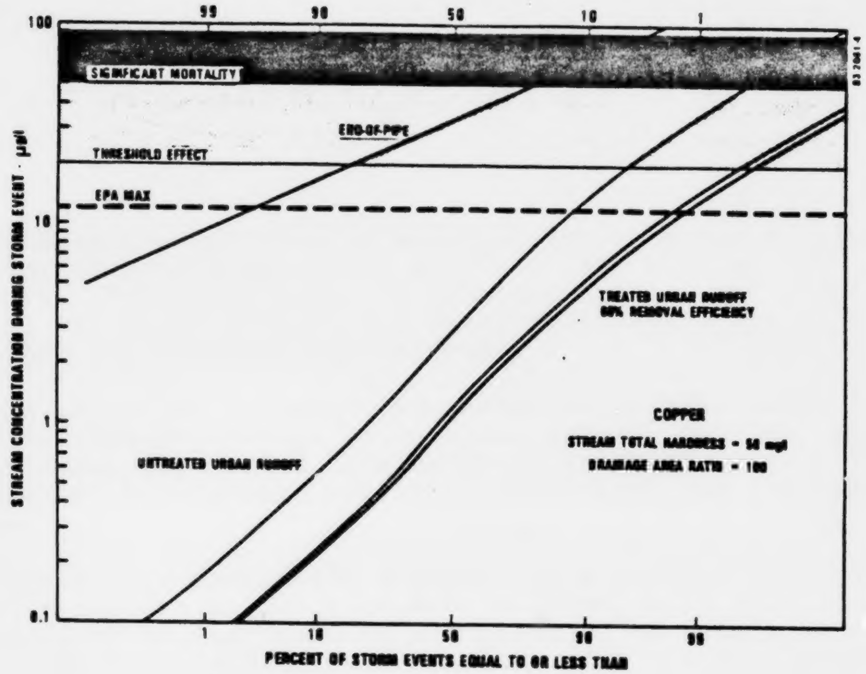

Figure 7-4. Probability Distributions of Pollutant Concentrations During Storm Runoff Periods

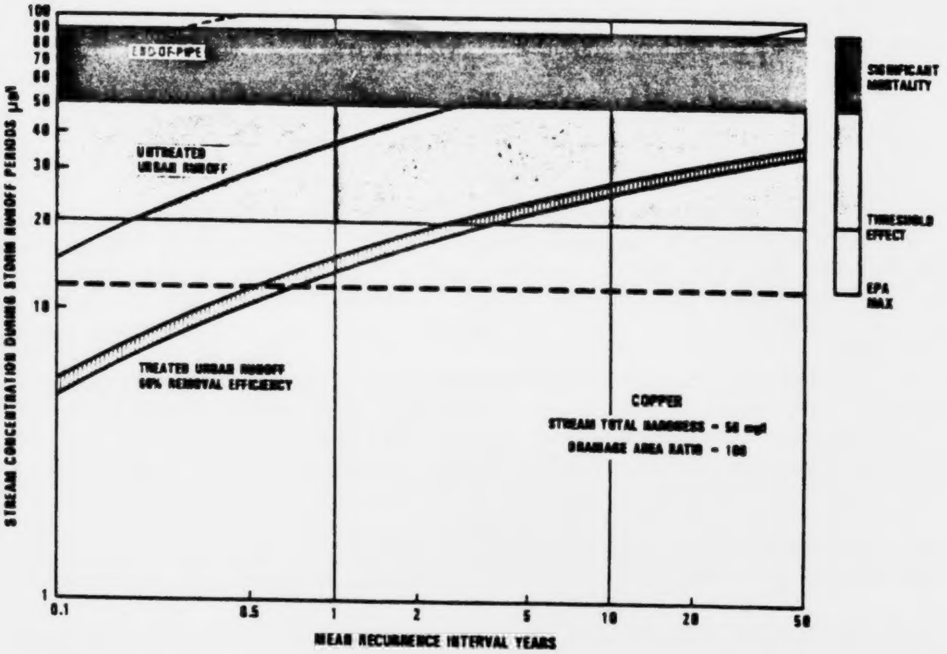

Figure 7-5. Recurrence Intervals for Pollutant Concentrations

AQUATIC IN-PLACE POLLUTANTS
(# 11)

ABSTRACT

Pollutants now residing in aquatic sediments may originate from sources currently operating and from past sources now discontinued. Point and nonpoint sources, spills, and atmospheric deposition, the major sources for water pollutants, are also the major sources for sediment contaminants.

Accumulations of contaminated sediments usually occur in areas having reduced current velocities, usually harbors, bays, lakes, and impoundments. Contaminants of greatest concern are usually metals, hydrophobic persistent organics, and the nutrient phosphorus.

Sediments at a particular site may be a concern (a) because ecological structure or function are believed to be impacted, (b) because fish tissue residues are elevated to levels that are believed to be hazardous to human health, or (c) simply because contaminant concentrations in sediment seem unusually high.

The overall extent and severity of the problem are uncertain. However, there are hundreds of sites with toxicant concentrations at levels of concern to environmental scientists and managers, and perhaps thousands of lakes and ponds with eutrophication exacerbated by sediment phosphorus cycling.

DISCUSSION

Pollutants currently residing in aquatic systems may be termed "in-place" pollutants. For a particular water body at a particular time the quantity of a pollutant in-place is determined by the past rates of (a) pollutant input to the system and (b) pollutant depuration by the system.

Depuration processes act to reduce concentrations by eliminating pollutant from the system. Physical processes (such as downstream transport or burial under new sediment) transfer material elsewhere. On the other hand, chemical processes (such as biological degradation) change the identity and properties of the material. Depuration rates are usually much slower for the bottom sediments than for the overlying waters; consequently, the term "in-place" is generally associated with sediment pollutants.

The sources of pollutants to aquatic sediments are the same as those to surface waters: primarily point and nonpoint sources, spills, and atmospheric inputs. As the Comparative Risk Project is addressing the pollutant sources to water separately, it might be assumed that the inclusion of in-place sediment pollutants as an independent problem was intended to address existing sediment

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contamination caused by past sources now discontinued. (In such case the regulatory choices would concern whether or not to intervene to hasten depuration of the aquatic system.) For the purposes of the Comparative Risk Project, however, it is not possible on a nationwide basis to distinguish sediment contamination problems on the of basis of whether or not their sources have been discontinued. Consequently, the coverage of this paper partially overlaps with other papers.

The ecological effects of sediment pollutants vary with the type of pollutant as follows.

Oxygen demanding materials:

Biological oxidation of such material reduces dissolved oxygen levels of the sediment interstitial (pore) water and the overlying water column, possibly impairing aquatic organisms. While dissolved oxygen problems are relatively common, sediment oxygen demand is only one contributor. Low current velocities and stratification promote sediment mediated dissolved oxygen problems. Nevertheless, as the half-life for sediment oxygen demand is probably relatively short, (perhaps measured in months), residuals from discontinued sources are not thought to be a problem.

Nutrients:

Lakes tend to trap the nutrient phosphorus released from their watersheds. Abating nutrient sources to lakes having a substantial history of algal nuisance generally will not solve the problem, because the cycling of nutrients between sediments and overlying waters will tend to support algal growth for many years. Consequently, in-place nutrients are a significant problem in many lakes and possibly some estuaries.

Toxicants:

Hydrophobic organics and metals tend to partition strongly to sediment. Ecological impairment by accumulations of such toxicants in bottom sediments is generally thought *not* to require mediation by the overlying waters (although sediment interstitial waters are suspected to play a key role). Benthic macroinvertebrates and bottom feeding fish may receive the most immediate exposure, although the resulting structural and functional changes or food web contamination may affect other organisms as well.

Regulatory efforts to address sediment contamination by toxicants are relatively recent. While field measurements of some sediment contaminants have been made over many years, reliable criteria for defining unacceptably high concentrations have not been developed. Some of the possible approaches for deriving criteria include: (a) comparison with "background" concentrations: a simple, often-used, but arbitrary approach lacking any relationship with ecological effects; (b) bioassay: direct measurements of sediment toxicity using single-species tests in the laboratory, without reference to particular chemical agents; (c) field-based criteria: maximum contaminant concentrations that biota have been observed to tolerate in the field, based on biological and chemical field measurements at many sites; (d) equilibrium sediment-water partitioning: existing water quality criteria applied to interstitial waters, assuming partitioning equilibrium.

The lack of established criteria for judging acceptable degrees of sediment contamination hampers assessment of the extent and severity of sediment contamination problems. Nevertheless, a nationwide survey of information on sediment contamination, contracted by OWRS, produced a number of findings:

(a) There are hundreds of sites in the U.S. having sediment contaminants at concentrations of concern to environmental scientists and managers. The basis for concern varies. At many sites all that is known is that the chemical concentrations in sediment seem abnormally high. At other sites contaminant concentrations in fish tissue are considered hazardous to human consumers. At some sites ecological effects have been found. [In-house analyses have found high correlations between sediment contaminant levels and macroinvertebrate diversity in widely differing rivers.]

(b) The magnitude of the problem in terms of areal extent and severity cannot now be rigorously assessed and is highly uncertain. Based on information available it was suspected that severe problems might exist in perhaps 1% of the river miles, 0.1% of the lake and estuary area, and 0.01% of the offshore marine area. (The U.S. has 1,800,000 miles of rivers, 62,000 square miles of lakes, and excluding Alaska 32,000 square miles of estuaries.)

(c) Municipal and industrial point sources, urban and agricultural runoff, combined sewer overflows, spills, mine drainage, and atmospheric deposition are frequently cited sources. Many of the worst cases of sediment contamination are associated with sources that have since been discontinued. However, the overall importance of residuals from discontinued sources is unknown.

(d) In addition to source locations, hydrological and benthal characteristics affect geographical patterns of sediment contamination. Fine grained particles with high surface-to-volume ratios and/or high organic content readily sorb hydrophobic pollutants. Contaminated sediments tend to accumulate where sediment laden streams enter quiescent waters. Harbor areas, both freshwater and marine, have been impacted most severely, although problems have been reported in all types of water bodies (streams, lakes, estuaries, and coastal waters).

(e) Sediment contaminants are most likely to be nonvolatile, persistent, and hydrophobic. Metals are most frequently cited as problems. PCBs, PAHs, and pesticides are also frequently mentioned.

(f) The persistence of contaminated sediments is difficult to predict; time frames are likely to be measured in years, decades, or possibly centuries. Depuration processes include downstream transport, burial, and chemical degradation. The effectiveness of potential actions to speed cleansing of sediments is likewise not well understood. Such actions may include dredging of sediments for disposal elsewhere, or in situ capping (burial).

The nationwide assessment gathered information on 155 sites. A summary of eight representative sites, shown in the Table 1, illustrates many of the variations in the nature of and knowledge of the problems. Ecological effects are only one of the concerns.

Primary References

Lyman, W.J. et al. 1986. An overview of sediment quality in the United States. EPA, OWRS. Draft.

McCarty, P.L. 1970. Chemistry of nitrogen and phosphorus in water. J. AWWA, 62 (2): 127.

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Table 1: Summary information for 8 of 155 sites considered in nationwide assessment.

Water Body	Contaminants	Origin of Contaminants	Perceived Impact
Boston Harbor	PAHs PCBs coprostanol	Many point sources Urban runoff Sludge disposal Sediment disposal Ship traffic	Structure and health of benthos
South River VA	Hg	Industrial spill	Fish tissue exceeds FDA action level
Jacksonville Port, FL	Metals	None mentioned	None mentioned
Bayou Casotte MS	Petroleum hydrocarbons	Industrial spills	None mentioned
Capitol Lake LA	PCBs	Industrial point source Spills Runoff	Ecosystem structure and function
Lake Erie, Western	Several organics	Unknown	None mentioned
L. Michigan, Sheboygan Harbor	PCBs	Discontinued industrial source	Fish consumption advisory
Commencement Bay WA	PCBs PAHs Other organics Some metals	Industrial sources	Fish tumors, fish tissue contamination

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SUBJECT: Summary of Contaminated Sludge/Ecological Risk Assessment

The sludges produced from many of the pollution control systems designed to clean-up contaminated air, water or soil have been safely recycled as soil conditioners, fill and construction materials. However, disposal of the ever increasing volumes of ''contaminated sludges'' produced as a byproduct of pollution control efforts can pose a number of serious environmental risks unless adequate precautions are taken to prevent contamination of ecosystems associated with the receiving environment.

Some of the key factors in evaluating the potential ecological risk associated with the disposal of contaminated sludge include the following:

- The volumes of sludges are growing dramatically as a result of increased pollution control activities
- Sludge quality is highly variable; some sludges may contain high concentrations of a wide variety of toxic pollutants
- Effective enforcement of regulatory requirements at sludge disposal sites is highly variable
- While little data exists on the number or extent of ecological problems which have occurred as a result of land disposal of contaminated sludges, anecdotal accounts and concerns abound
- Much of the extensive literature available on the fate and impact of individual chemicals that may be present in contaminated sludges is based upon controlled lab studies and it very difficult to translate lab measurements of effects upon individuals to potential effects upon natural populations
- Only limited attempts have been taken to date to document direct in-field impacts to natural ecosystems as a result of contaminated sludge disposal projects
- Examples do exist of past contaminated waste disposal practices creating serious threats to human health and incidents of extensive ecosystem degradation

An attempt was made at rating the ecological risk associated with the disposal of contaminated sludge under current plus reasonably anticipated future regulatory programs. This effort suggests that the disposal of contaminated sludge should not be expected to result in extensive damage to natural ecosystems where reasonably anticipated control programs are properly implemented. However, if the permitting/monitoring/enforcement efforts that are currently in place and anticpated to be implemented in the future are not carried out, the improper disposal of contaminated sludges could lead to major ecosystem damage.

RBastian20Nov86

SUBJECT: Contaminated Sludge/Ecological Risk Assessment

I. Introduction to Problem

Pollution control systems are designed to clean-up contaminated air, water, or soil. In most cases these systems not only produce clean air, water, or soil, but also concentrate many of the contaminants which have been removed into a residual "sludge." While the sludges produced from many of these treatment systems have been safely recycled as soil conditioners, fill and construction materials, disposal of "contaminated sludges" can pose a number of serious environmental risks unless adequate precautions are taken to prevent contamination of ecosystems associated with the receiving environment. Current sludge disposal practices involve various forms of land application, landfilling, incineration and ocean disposal - thus, leading to the potential for interacting with both terrestrial and aquatic ecosystems.

II. Detailed Description of Problem

SOURCES .... As noted in a recent OW cross-media analysis of sludge management, the management of municipal and industrial sludge is a growing problem. The sources involve over 15,000 municipal wastewater treatment plants (which also serve at least 87,000 industrial contributors), and over 38,000 industrial facilities nationwide. Since 1972, municipal sludge has doubled in volume to over 7 million dry metric tons annually. Another doubling of municipal sludge quantities is expected by the year 2000 as a result of both the construction of new publicly owned treatment works (POTWs) and the addition of better treatment at some existing POTWs. In addition, the industrial sector produces an even larger volume of sludge from industrial wastewater processing: 4 million dry metric tons of hazardous sludges and 200 million dry metric tons of non-hazardous sludges annually. When including the sludge volume generated from all industrial pollution treatment, including scrubbing of furnace stacks and other air emissions, the total amount of industrial pollution treatment sludges are expected to reach more than 262 million tons annually by 1987. (see Table 1)

EXPOSURES .... Sludge quality is highly variable. Some sludges are relatively "clean" and can be used for beneficial purposes while other sludges may contain high levels of toxic organic or inorganic chemical pollutants, and/or pathogens. (see Table 3) The relatively clean sludges are currently used or disposed of by landfilling; land application to agricultural land, forests, mined lands, etc.; given away or sold for use as soil conditioners; incinerated; disposed of into the ocean through outfalls or by ocean dumping; or stored for future use or disposal. Other sludges may contain high concentrations of a wide variety of toxic pollutants; a number of industrial sludges are listed hazardous wastes. The more contaminated sludges generally are stored on-site or transported to hazardous waste treatment, storage, or disposal facilities - often hazardous waste landfills, lagoons, or incinerators. (see Table 2) Concern has been expressed over the adequacy of such facilities to assimilate, contain or destroy the contaminants present in these sludges so as to prevent their escape into nearby environments.

CONTROLS .... On paper, there are existing EPA regulations and programs (and State programs) that could be expected to control nearly all of the sludge use and disposal practices in one manner or another. However, the regulation of sludge disposal management involves provisions under many different laws (e.g., CWA, CAA, RCRA, MPRSA, TSCA) and corresponding Agency programs. A recent OW cross-media analysis of sludge management provided the following observations concerning the Agency's current approach to regulating sludge management practices:

- EPA's approach to sludge management is not one that has been clearly laid out.
- The regulation of different sludges is inconsistent across the vairous EPA media.
- The Agency may not be effectively regulating all industrial sludges.
- Better information on the toxicology, treatability and generation of specific pollutants is needed to determine which pollutants to regulate in sludge.
- There is no new funding for sludge management and enforcement, despite potential new burdens for some program activities.

The conclusions of the OW cross-media study included:

- The sludge problem is important and pervasive, and the municipal sludge problem, in praticular, is the subject of intense Congressional and public interest.
- For the most part, Agency sludge management related program activities are receiving adequate priority. The most noteworthy exceptions are non-hazardous industrial sludge management (where sludge volume is greatest but where attention and funding are minimal) and State Programs.

STATUS OF AVAILABLE INFORMATION .... Information-wise, we are in fairly good shape concerning information on the fate and effect of only some of the many different chemical pollutants and pathogens associated with sludges. Yet our overall information-base on recommended municipal sludge management practices is quite good, especially when compared with the available information associated with the disposal of many of the industrial sludges that may contain high concentrations of various toxic pollutants. While it is clear that a better understanding of the fate and effect of all chemical pollutants that may be present in municipal sludge would be helpful in assuring adequate protection of public health and the environment, to date few cases of significant environmental problems have been documented as resulting from the reuse or disposal of municipal sludge even when good management practices have not been followed. On the other hand, a number of industrial sludges are listed hazardous wastes and numerous Superfund sites have been listed as a result of past poor industrial sludge disposal practices. Apparently as a result of the Agency's focus on protecting human health, there appears to have been only limited attempts taken to date to document direct in-field impacts to natural ecosystems as a result of contaminated sludge disposal practices. While elevated levels of toxic metals and organic compounds have been documented as present in various plant and animal tissues in flora and fauna present in or near certain sludge reuse and disposal facilities, just what the longterm impacts of these increased body burdens mean has not been determined or studied to any serious extent.

III. Evaluation of the Problem

Terrestrial and Freshwater Ecosystems

Impacts on terrestrial and affiliated freshwater ecosystems resulting from land-based disposal or use of contaminated sludge are quite distinct from those of ocean disposal. Because man is generally in more direct contract with terrestrial ecosystems, the strategy for waste disposal on land has traditionally been one of containment. There has also been considerable use of land application systems designed to both treat and recycle wastes of an acceptable quality in a more dispersive manner in which the soil serves as a "living filter" to help treat the waste while the waste serves as an organic nutrient source or soil conditioner. In either case, however, concerns over impacts from land-based treatment and disposal or application practices are usually less focused on large-scale contamination of natural resources or destruction of ecological systems within the disposal site, but rather directed at the potential export of contaminants to other ecological systems, contamination of surface- and groundwater resources, secondary effects on valuable natural and agricultural lands, and direct threats to human health.

Specific ecological (non-human) concerns for land disposal include: (1) the transport of toxic organics and heavy metals through surface and groundwaters or plant uptake by vegetation grown on sludge-amended soils, with potential ecological effects, such as contamination of animal foodchains; and (2) the export of nutrients, toxic organics and heavy metals from land disposal sites (e.g., via leachates or surface runoff) to non-target ecological systems, such as nearby streams and wetlands, and the possible destruction of wildlife habitats and unique ecosystems. Selection of land disposal sites, therefore, must consider not only the hydrological and geological suitability of the site for treatment, containment or recycling of wastes, but also the resiliency of the ecosystem and adjacent ecosystems to damage. Some of the engineering and environmental considerations applicable to land disposal practices are presented in Figure 1.

There are a large number of terrestrial sludge treatment and disposal options currently in use, including both systems designed primarily for waste disposal, such as landfills, deep well injection systems, storage pits, ponds and lagoons, and high rate land application systems; and others designed with recycling as a intergral aspect of disposal. Treatment and recycling systems may involve a variety of managed natural or man-made "ecosystems" (e.g., agricultural lands, forests, disturbed lands, etc.). In many cases the terrestrial ecosystems can serve as an integral part of waste treatment and reuse systems rather than just a location for waste disposal. In certain instances wastes can and have been effectively used as a component of ecosystem management programs such as enhancing the diversity and productivity of such areas as mine spoils and other drastically disturbed lands (Benforado and Bastian, 1985; Bastian, 1982; Sopper et al., 1982; Schaller and Sutton, 1978).

The major concerns in site selection for land disposal practices are to ensure that: (1) groundwater and surface water resources in and around the disposal site do not become contaminated beyond acceptable levels; (2) land-use patterns are not compromised; (3) unique ecosystems and habitats are preserved; and (4) soil-amendments do not result in transfer of contaminants to plants and animals and to the human food chain (U.S. NRC, 1984a; U.S. EPA 1983, 1981). Predictions of contaminant migration to groundwater and surface water and to non-target ecosystems require an understanding of the processes controlling transport, hydrodynamic dispersion, and the physical, chemical, and biolgical reactions that affect contaminant distributions at a given site for a given period of time (U.S. NRC, 1984c). Criteria used for the selection of a disposal containment site, therefore, are such that the geologic, geochemical, and hydrologic characteristics should isolate the wastes from the biosphere for a long period of time. On the other hand, criteria for recycling projects are generally more dependent upon limiting the contaminant levels in the wastes involved and controlling loading rates to what can be effectively treated and/or used by the natural or man-made ecosystems involved.

It is when these basic criteria for waste disposal and recycling projects are not followed that ecosystem impacts are most likely to occur. The long list of potential Superfund sites serves as a legacy of bad waste disposal practices that have been practiced in the past. Although limited, some data have been generated that suggest potential ecological problems associated with such sites. The continuing studies since 1979 of voles living near New York's imfamous Love Canal in the City of Niagra Falls undertaken by John Christian and others from SUNY-Binghamton have shown that voles living close to the waste disposal site appear to have shorter life spans and suffer from delayed maturation in males, reproductive problems in females, liver damage when compared to animals living further away from the site.

While there are few data on the number or extent of ecological problems which have occurred as a result of land disposal of contaminated sludges, anecdotal accounts and concerns abound. Situations where excessive loading rates or inappropriate disposal site characterists may have led to sludge-borne contaminants in runoff from fields or leachates from landfills reaching nearby surface streams to cause fish kills or contaminate water supplies and vegetation have been reported. While enhanced wildlife reproduction and general ecosystem production rates often appear to increase on well designed and operated sites, elevated levels of sludge-borne contaminants in the blood stream and vital organs have been reported in small mammals and other consumers of vegetation grown on sludge amended sites (Cole et al, 1986; Page et al, 1983; Davis et al, 1983; Sopper et al, 1982; Anderson et al, 1982; Bledsoe, 1981). Clearly, increased vegetation uptake of many sludge-borne contaminants has been demonstrated at many land disposal sites, as has elevated levels of metals in certain body tissues by domestic animals either fed crops grown on sludge amended fields or directly fed dried sludge as a part of their feed ration (CAST, 1976; Bitton et al, 1980; Page et al, 1983; Page and Logan, 1986). But just what sub-lethal increases in body burdens of such contaminants in wildlife which consume this vegetation may mean over the long term to the ecosystem involved has yet to be determined or even studied to any serious extent.

Marine Ecosystems

The impacts of contaminated sludge or other waste disposal in the marine environment is dependent on the composition and volume of waste involved and on the dispersal and transport characteristics of the site used for disposal. Contaminants of most concern to marine ecosystems, such as pathogenic microorganisms, trace metals and toxic organic compounds are associated primarily with particulate matter. Transport of contaminants within coastal areas coincides with sediment transport processes and, thus, such material tends to accumulate in depositional areas. There have been numerous examples around the world showing how sediment deposits in coastal areas reflect waste disposal histories. The distribution, fate, and effects of wastes disposed of in the ocean are governed by the physical, chemical, and biological processes that generally reduce the concentration, alter the chemical form and ultimately eliminate them from the water column. Transfer of contaminants to marine biota and disturbance of ecological systems for the most part are dependent on the availability and persistence of contaminants in benthic ecosystems.

With the exception of extremely hazardous wastes, such as high level radioactive wastes that may be containerized before disposal and dredge material that may be contained in a submarine pit and capped, the containment strategy generally employed as a basis for land disposal practices is generally not feasible for disposal of most wastes in the ocean. Resuspension and transport of materials by bottom currents and degradation and recycling of materials in biogeochemical cycles are natural dispersal mechanisms (see Figure 2). Waste disposal in areas of restricted circulaiton, such as basins, will possibly permit the buildup of biological systems that can accelerate the decomposition of relatively non-toxic wastes in a fashion analagous to composting on land, but this has not been well studied.

In general, degradation of benthic habitats as a result of waste disposal has usually been attributed to high levels of organic enrichment in bottom sediments (Boesch, 1982; Pearson and Rosenberg, 1978). The delineation between observed benthic effects of waste disposal at nondispersive sites and no observed effects at dispersive sites suggests that wide dispersal may be not only the most feasible disposal option but also the preferred one. However, unlike the situation with land application practices, little effort has been directed toward managing or stimulating the beneficial effects, such as increased productivity (Ryther and Dunstan, 1971), that may result from waste disposal in the marine environment.

Ecological concerns with contaminated sludge disposal in the ocean include: (1) uptake and accumulation of chemical contaminants in marine organisms to toxic levels, their effects on the survival and reproduction of marine organisms and the resulting impact on marine ecosystems, and (2) the release of biodegradable organic matter and nutrients, which under quiescent conditions may result in localized eutrophication, organic enrichment, and oxygen depletion (Capuzzo et al., 1985). To minimize organic loading and accumulation of sludge contaminants in marine organimsms, disposal of these wastes in the ocean should occur in areas where horizontal dispersion distributes the waste over a wide geographic area, this preventing overloading of natural microbial and biochemical processes, severe alterations in macrobenthic communities, and accumulation of contaminants in the benthos. Deep-water or offshore disposal of contaminated sludges offers several advantages in meeting these criteria in comparison with nearshore disposal - specifically, greater dilution and dispersion of the wastes and reduced potential of contaminants being transferred through the marine foodchain.

As with terrestrial systems, it is when these basic concepts for ocean disposal are not followed that ecosystem impacts are most likely to occur. While there are only a few examples of ocean disposal of contaminated sludge and related wastes in the U.S. today, the impacts of both current and past practices continue to face EPA as a regulatory agency. Ocean disposal of sludge (and/or poorly treated wastewater) through outfalls in Southern California, into Puget Sound, and into Boston Harbor, and ocean dumping at the 12 mile site in the New York Bight lead to dramatic changes in benthic communities, including increases in total productivity and reductions in species numbers (see Myers and Harding,1983; and especially Mearns and Young, 1983). Increases in benthic fish body-burdens of contaminants and certain diseases such as fin erosion and skin tumors in these areas have also been noted. Contaminated sediments from past industrial discharges (in some cases with pollutant concentrations much higher than most sludges produced today) have lead to closure of extensive shellfish beds and Superfund site designations in Puget Sound and Narragansett Bay. Consideration is still being given to the possible designation of a portion of the Santa Monica Basin near Palos Verdes Peninsula off Southern California due to high levels of DDT and PCB's in bottom sediments which accumulated as a result of contaminated industrial wastes being discharged through a municipal outfall in past years.

Degree of Ecological Risk from Contaminated Sludge

Much of the extensive literature that is available on the fate and impact of individual chemicals that may be present in contaminated sludges is based upon controlled laboratory studies. And it must be remembered that it is very difficult to translate lab measurements of effects upon individuals to potential effects upon natural populations since the latter are also influenced by interactions among population members and with the physical environment (Levin et al, 1984). However, at least in the case of sewage sludge, there has been a considerable amount of field data collected on the fate of nutrients and trace metals, and to a lesser extent toxic organic compounds and pathogens, under a wide array of environmental conditions that can help temper the conclusions that may be drawn from using only lab data.

Table 4 summarizes the types of concerns for both ecological damage and human health impacts that effective management of waste (including contaminated sludge) systems should consider for a variety of ecosystems. Such a framework may be useful in evaluating the ecological concerns of cross ecosystem comparisons of contaminated sludge disposal impacts. Our knowledge of the dynamics of these ecosystems is by no means complete. Yet, we have sufficient knowledge to make reasonable first-order predictions of the impacts of contaminated wastes on ecosystem processes to avoid serious threats to human health, as resulted from mercury disposal in Minimata Bay, and incidents of extensive ecosystem degradation. Consideration of these ecological principles combined with engineering design for specific waste disposal or reuse systems should become an integral component of the decision making process for waste management.

Rating of ecological risk

An attempt at rating the ecological risk associated with the disposal of contaminated sludge under current plus reasonably anticipated future regulatory programs using the method adopted by the workgroup follows:

	Recommended Rating
Freshwater ecosystems	
o buffered & unbuffered lakes	M
o buffered & unbuffered streams	L
Marine and estuarine ecosystems	
o coastal ecosystems	M
o open ocean ecosystems	L
o estuaries	M
Terrestrial ecosystems	
o coniferous & deciduous forests	L
o grassland ecosystems	M
o desert and semi-arid ecosystems	L
o alpine and tundra ecosystems	L
Wetland ecosystems	
o buffered & unbuffered freshwater isolated wetlands	M
o freshwater flowing wetlands	M
o saltwater wetlands	L

This rating suggests that the disposal of contaminated sludge should not be expected to result in extensive damage to natural ecosystems where current plus reasonably anticipated control programs are properly implemented. However, since contaminated sludges are clearly a potentially significant source of BOD, solids, nutrients, toxic inorganics and organics, and pathogens, if the permitting/monitoring/enforcement efforts that are currently in place and anticipated to be implemented in the future are not carried out, this rating could well change dramatically and suggest that the disposal of contaminated sludges could lead to major ecosystem damage.

__FOOTNOTE__: For years extensive research was undertaken to study radiation effects on ecosystems. As as a result there was extensive literature generated on the responses of many species to various levels and types of radiation exposure. In some cases large-scale field studies were even undertaken (e.g., Hubbard Brook and Puerto Rico studies as well as longterm monitoring of the Nevada and South Pacific Test Sites). Yet, much of the research as well as our regulatory considerations of the ecosystem effects associated with radiation has been based on extrapolations from laboratory studies on single organisms and populations - in spite of the known difficulties in extrapolating from lab experiments to natural systems and the lack of longterm observations on responses of natural ecosystems to chronic low level irradiation - and field studies which support the suggestion that extrapolation from lab results may overestimate the radio-resistance of free ranging animal populations, probably as a result of other sources of stress on these populations (see Cushing, 1976).

[__NOTE__: Much of the content of this draft paper was based upon a paper, titled "Ecological and Human Health Criteria for Cross Ecosystem Comparison of Impacts of Waste Management Pracitces" prepared by Judith Capuzzo and John Teal from Woods Hole along with Bob Bastian from EPA which was presented the NATO conference on "Scientific Basis for the Role of the Oceans as a Waste Disposal Option" held 24-30 April 1985 in Vilamoura,Portugal]

References

Anderson, T.J., G.W. Barrett, C.S. Clark, V.J. Elia and V.A. Majeti. 1982. Metal concentrations in tissues of meadow voles from sewage sludge-treated fields. JEQ 11(2):272-277.

Bakelaar, R. and E. Odum. 1978. Community and population level responses to fertilization in an old-field ecosystem. Ecology 59:660-671.

Bastian, R.K. 1982. Natural treatment systems in wastewater treatment and sludge management. Civil Engineering-ASCE 52(5):62-67.

Benforado, J. and R.K. Bastian. 1985. Natural waste treatment. IN: McGraw-Hill Yearbook of Science and Technology. McGraw-Hill Book Co., New York, NY. pp. 33-49.

Bitton, G., B.L. Damron, G.T. Edds and J.M. Davidson (eds.). 1980. Sludge - Health Risks of Land Application. Ann Arbor Science, Ann Arbor, MI. 367pp.

Bledsoe, C.S. (ed.) 1981. Municipal sludge application to Pacific Northwest forest lands. Institute of Forest Research Rept. No. 41, Univ. of Washington, Seattle, WA. 155 pp.

Boesch, D.F. 1982. Ecosystem consequences of alterations of benthic community structure and function in the New York Bight region. IN: C.F. Mayer (ed.), Ecological Stress and the New York Bight: Science and Management. Estuarine Research Federation, Columbia, SC. pp. 543-568.

Capuzzo, J.M., J.M. Teal and R.K. Bastian. 1985. Ecological and Human Criteria for Cross Ecosystem Comparison of Impacts of Waste Management Practices. Paper presented at the NATO Conference on Scientific Basis for the Role of the Oceans as a Waste Disposal Option held April 24-30, 1985 in Vilamoura, Portugal.

Cook, C.W. 1976. Surface-mine rehabilitation in the American West. Enviorn. Conserv. 3:179-183.

Cole, D.E., W.L. Nutter and C. Henry (eds.). 1986. Forest Utilization of Municipal and Industrial Wastewater and Sludge. Proceedings of an International Symposium held June 25-28, 1985 in Seattle, WA. University of Washington Press.

Council for Agricultural Science and Technology. 1976. Report No. 64 Application of Sewage Sludge to Cropland: Appraisal of Potential Hazards of the Heavy Metals to Plants and Animals. EPA-430/9-76-013. Office of Water Program Operations, Washington, D.C. 63pp.

Cushing, C.E., Jr. (ed.). 1976. Radioecology and Energy Resources. The Ecological Society of America, Special Publ. No. 1. Dowden, Hutchinson & Ross, Inc., Stoudsburg,PA. 401pp.

Davis, R.D., G. Hucker and P. L'Hermite (eds). 1983. Environmental Effects of Organic and Inorganic Contaminants in Sewage Sludge. D. Reidel Publ. Co., London. 257pp.

Godfrey, P.J., E.R. Kaynor, S. Pelczarski and J. Benforado. 1985. Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Co., New York, NY. 473pp.

Gray, J.S. 1979. Pollution-induced changes in populations. Philos. Trans. R. Soc. Lond. Biol. Sci. 286:545-561.

Herricks, E.E. and J. Cairns, Jr. 1982. Biological monitoring. III. Receiving system methodology based on community structure. Water Res. 16:141-153.

Holdgate, M.W. 1978. Final Discussion. IN: M.W. Holdgate and M.J. Woodman (eds.). The Breakdown and Restoration of Ecosystems. Plenum Press, New York, NY. pp. 465-473.

Kelly, J.R., M.A. Harwell and A.E. Giblin. 1982. Comparisons of the Processing of Elements by Ecosystems: I. Nutrients II. Metals. ERC Rept. No. 21. Ecosystem Research Center, Cornell Univ., Ithaca, NY.

Kirchner, T.B. 1977. The effects of resource enrichment on the diversity of plants and arthropods in a short-greass prairie. Ecology 58:1334-1344.

Levin, S.A., K.D. Kimball, W.H. McDowell and S.R. Kimball (eds.). 1984. New Perspectives in Ecotoxicology. Env. Mgnt. 8(5):376-442.

McIntosh, R.P. 1980. The relationship between succession and the recovery process in ecosystems. IN: J. Cairns (ed.). The Recovery Process in Damaged Ecosystems. Ann Arbor Science, Ann Arbor, MI. pp. 11-62.

Mearns, A.J. and D.R. Young. 1983. Appendix A: Characteristics and Effects of Municipal Wastewater Discharges to the Southern California Bight, A Case Study. IN: Meyers, E.P. and E.T. Harding (eds.). Ocean Disposal of Municipal Wastewater: Impacts on the Coastal Environment. Sea Grant Program, Massachusetts Institute of Technology, Cambridge, MA. pp. 761-819.

Myers, E.P. and E.T. Harding (eds.). 1983. Ocean Disposal of Municipal Wastewater: Impacts on the Coastal Environment (2 vols). Sea Grant Program, Massachusetts Institute of Technology, Cambridge, MA. 1115pp.

Milton, W. 1947. The yield, botanical and chemical composition of natural hill herbage under manuring, controlled grazing and hay conditions. I. Yield and botanical. J. Ecol. 35:65-89.

Nixon, S.W., C.D. Hunt and B.L. Nowicki. 1984. The retention of nutrients (C, N & P), heavy metals (Mn, Cd, Pb & Cu), and petroleum hydrocarbons in Narragansett Bay. Paper presented at SCOR Seminar on Biogeochemical Processes at the Land-Sea Boundary, October 22-24, 1984, in Roscoff, France.

Page, A.L. and T.J. Logan (eds.). 1986. Effects of Sewage Sludge Quality and Soil Properties on Plant Uptake of Sludge-Applied Trace Constituents. Proceedings of and EPA Sponsored Workshop, November 13-16, 1985, in Las Vegas, NV. (IN PRESS)

Page, A.L., T.L. Gleason III, J.E. Smith, I.K. Iskandar and L.E. Sommers (eds.). 1983. Proceedings of the 1983 Workshop on Utilization of Wastewater and Sludge on Land. Univ. of California-Riverside, CA. 480pp.

Patrick, R., M.H. Hohn and J.H. Wallace. 1954. A new method for determining the pattern of the diatom flora. Notulae Naturae. No. 259.

Pearson, T.H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution in the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16:229-311.

Race, M.D. and D.R. Cristie. 1982. Coastal zone development: Mitigation, marsh creation, and decision-making. Environ. Mgmt. 6: 317-328.

Ryther, J.H. and W.M. Dunstan. 1971. Nitrogen, phosphorus and eutrophication of the coastal marine environment. Science 171: 1008-1013.

Schaller, F.W. and P. Sutton (eds.). 1978. Reclamationof Drastically Disturbed Lands. ASA, CSSA, SSSA, Madison, WI. 742pp.

Silvertown, J. 1980. The dynamics of a grassland ecosystem: Botanical equilibrium in the Park-Grass experiment. J. Appl. Biol. 17:491-504.

Sopper, W.E., E.M. Seaker and R.K. Bastian (eds.). 1982. Land Reclamation and Biomass Production with Municipal Wastewater and Sludge. Penn State Univ. Press, University Park, PA. 524pp.

Specht, R.L. 1963. Dark Island heath (Ninety Mile Plain, South Australia). VII. The effect of fertilizers on composition and growth, 1950-1960. Austral. J. Bot. 11:62-66.

Steele, J.H. 1985. A comparison of terrestrial and marine ecological systems. Nature 313:355-358.

Stickel, W.H. 1975. Some effects of pollutiants in terrestrial ecosystems. IN: A.D. McIntyre and C.F. Mills (eds.). Ecological Toxicology Research. Plenum Press, New York, NY. pp. 25-74.

Teas. H.J. 1977. Ecology and restoration of mangrove shorelines in Florida. Environ. Conserv. 4:51-58.

U.S. Environmental Protection Agency. 1981. Process Design Manual for Land Treatment of Municipal Wastewater. Center for Environmental Research Information, Cincinnati, OH. EPA-625/1-81-013. 480pp.

U.S. Environmental Protection Agency. 1983. Process Design Manual for Land Application of Municipal Sludge. Center for Environmental Research Information, Cincinnati, OH. EPA-625/1-83-016. 434pp.

U.S. National Research Council. 1984a. Disposal of Industrial and Domestic Wastes. Land and Sea Alternatives. National Academy Press, Washington, D.C. 210pp.

U.S. National Research Council. 1984b. Ocean Disposal Systems for Sewage Sludge and Effluents. National Academy Press. Washington, D.C. 126pp.

U.S. National Research Council. 1984c. Groundwater Contamination. National Academy Press, Washington, D.C. 179pp.

Willis, A. 1963. Braunton burrows: The effects on the vegetation of the addition of mineral nutrients to the dune soils. J. Ecol. 51:353-374.

Woodwell, G.M. 1970. The energy cycle of the biosphere. Sci. Am. 233:64-74.

Woodwell, G.M. and R.H. Whittaker. 1968. Effect of chronic gamma irradiation on plant communities. Quart. Rev. Biol. 43:42-55.

Zedler, J.B., M. Josselyn and C.P. Onuf. 1982. Restoration techniques, research and monitoring: Vegetation. IN: M. Josselyn (ed.). Wetland Restoration and Enhancement in California. Calif. Sea Grant College Program Rept. No. T-CSGCP-007, La Jolla, CA. pp.63-72.

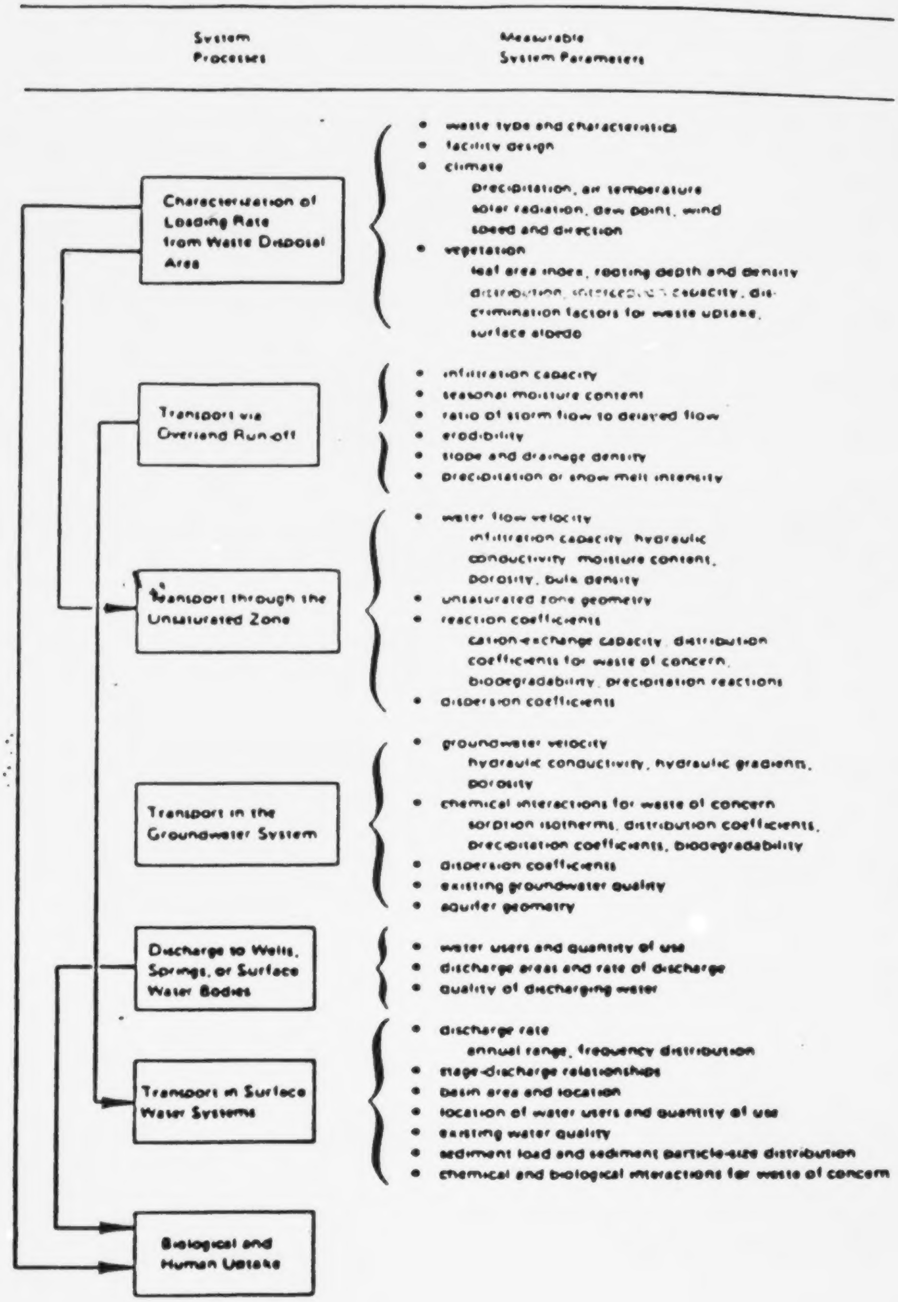
System Processes
Measurable System Parameters
Characterization of Loading Rate from Waste Disposal Area
waste type and characteristics
facility design
climate
precipitation, air temperature
solar radiation, dew point, wind
speed and direction
vegetation
leaf area index, rooting depth and density
distribution, interception capacity, dis-
crimination factors for waste uptake,
surface albedo
Transport via Overland Run-off
infiltration capacity
seasonal moisture content
ratio of storm flow to delayed flow
erodibility
slope and drainage density
precipitation or snow melt intensity
Transport through the Unsaturated Zone
water flow velocity
infiltration capacity, hydraulic
conductivity, moisture content,
porosity, bulk density
unsaturated zone geometry
reaction coefficients
cation-exchange capacity, distribution
coefficients for waste of concern,
biodegradability, precipitation reactions
dispersion coefficients
Transport in the Groundwater System
groundwater velocity
hydraulic conductivity, hydraulic gradients,
porosity
chemical interactions for waste of concern
sorption isotherms, distribution coefficients,
precipitation coefficients, biodegradability
dispersion coefficients
existing groundwater quality
aquifer geometry
Discharge to Wells, Springs, or Surface Water Bodies
water users and quantity of use
discharge areas and rate of discharge
quality of discharging water
Transport in Surface Water Systems
discharge rate
annual range, frequency distribution
stage-discharge relationships
basin area and location
location of water users and quantity of use
existing water quality
sediment load and sediment particle-size distribution
chemical and biological interactions for waste of concern
Biological and Human Uptake

Figure 1. Engineering and environmental considerations related to waste migration from land disposal practices. From: U.S. NRC (1984a).

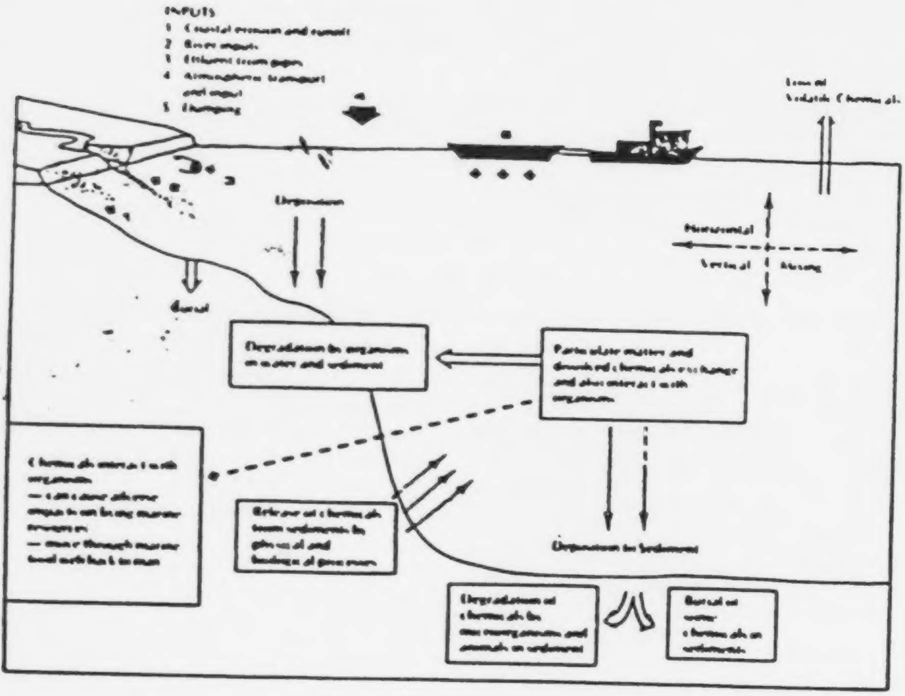
INPUTS
1 Coastal erosion and runoff
2 River inputs
3 Effluent from pipes
4 Atmospheric transport and input
5 Dumping
Loss of Volatile Chemicals
Deposition
Horizontal
Vertical Mixing
Burial
Degradation by organisms in water and sediment
Particulate matter and dissolved chemicals exchange and also interact with organisms
Chemicals interact with organisms — can cause adverse impacts on living marine resources — move through marine food web back to man
Release of chemicals from sediments by physical and biological processes
Deposition to Sediment
Degradation of chemicals by microorganisms and animals in sediment
Burial of some chemicals in sediments

Figure 2. Input and transport of wastes in marine ecosystems. From: Farrington et al. (1982). Artist, Kevin King (OCEANUS Magazine).

Table 1. Approximate Mass of Sludge Generated by Pollution Control Activities[a]

Type of Sludge	Total Sludge (DMT/yr)
Air Pollution Control	
- electric utilities[b]	50×10^6
- other	43×10^6
Drinking Water Treatment[c]	4×10^6
Industrial Wastewater Treatment[d]	16×10^6
Municipal Wastewater Treatment	7×10^6

[a] based on data from JRB, Assoc. December 1983 Report to U.S. EPA, ''Inventory of Air Pollution Control, Industrial Wastewater Treatment and Water Treatment Sludges''

[b] fly ash & scrubber sludges

[c] surface & groundwater

[d] iron & steel, inorganic chemicals, food processing, and pulp & paper manufacturing account for 90% of the total

Table 2. Current Disposal Practices for Sludges Generated by Pollution Control Activities

Type of Sludge	Lagoons	Land-fill	Land Appl.	D&M/reuse	Incin.	Ocean Disp.
Air Pollution Cont.	X	X		X		
Drinking Water Trt.	X	X	X			
Industrial Waste-water Trt.	X	X	X	X	X	x
Municipal Waste-water Trt.	X	X	X	X	X	X

Table 3. Common Sludge Constituents[a]

Type of Sludge	Conventional Organics	Conventional Inorganics	Toxic Metals	Toxic Organics	Nutrients	Hazardous Waste
Air Pollution Control	None	High	Medium	None	Low	Rarely
Drinking Water Treatment	Low	High	Low	Low	Low	No
Industrial Wastewater	Low-High	Low-High	Low-High	Low-High	Low-High	Several Catagories Listed
Municipal Wastewater Treatment	High	Low-High	Low-High	Low-High	Low-High	Rarely

[a] based on data from JRB, Assoc., December 1983, Report to U.S. EPA, ''Inventory of Air Pollution Control, Industrial Wastewater Treatment and Water Treatment Sludges''

Table 4. Ecological and Human Health Concerns of Waste Disposal Impacts in Aquatic and Terrestrial Environments (adapted from U.S. NRC, 1984a).

Type of Environment	Species Extinction	Habitat Loss	Elevated Nutrients	Recoverability	Containment	Remedial Action	Uncertainty	Visibility	Pathogen Route to Society	Toxicant Route to Society
LAND										
Disturbed Lands[a]	1	0	1	0	1	0	1	3	3	3
Remnants[b]	0	3	1	1	1	1	1	3	3	3
Temperate Forest	1	1	1	2	1	1	1	2	2	2
Temperate Grassland	1	1	1	1	1	1	1	2	2	2
Pasture	0	0	0	1	1	1	1	3	3	3
Agricultural Land	0	1	0	2	2	1	1	3	3	3
Arid Land	2	2	1	2	1	2	2	2	1	1
Arctic Land	0	1	1	3	1	3	3	1	1	1
FRESHWATER										
Lake	1	3	3	2	3	3	2	3	3	3
Stream	3	3	2	2	3	3	2	2	3	3
Wetland	3	3	3	2	3	3	3	2	2	2
Groundwater	2	1	3	3	3	3	3	0	3	3
MARINE										
Wetlands (U.S. East Coast)	1	3	2	2	3	3	2	3	3	3
Wetlands (U.S. West Coast)	3	3	2	2	3	3	2	3	3	3
Estuaries	3	3	2	2	3	3	2	3	3	3
Coastal Areas	1	2	1	1	3	3	2	1	2	3
Open Ocean	1	1	0	3	3	3	3	0	1	1

NOTES: Species Extinction: 3 = greatest concern.
Habitat Loss -loss of a significant portion of a habitat type: 3 = greatest concern.
Elevated Nutrients: 3 = highest probability of change to ecosystem.
Recoverability -ability of system to repair itself after input ceases: 3 = slowest recovery, decades to centuries; 1 = rapid recovery, years.
Containment -ability of unmodified system to restrict spread of inputs: 3 = greatest difficulty.
Remedial Action -ease with which we can repair damage to ecosystem: 3 = greatest difficulty.
Uncertainty: 3 = highest uncertainty.
Visibility: 3 = most visible.
Pathogen Routes to Society: 3 = highest probability of reaching society.
Toxicant Routes to Society: 3 = highest probability of reaching society.

[a] Disturbed Lands -land highly modified by human activity.
[b] Remnants -isolated natural spots within developed or otherwise highly modified area.

STATISTICS ON SEWAGE SLUDGE

- 15,300 POTWs generate 7.6 million dry metric tons of sewage sludge per year (as compared to 204 million dry metric tons of industrial sludges)
- Sewage sludge is disposed of as follows:
  - 46.4% by landfilling and surface impoundments (1.5% by mono-landfilling) (25% in 1976)
  - 25.4% by land application including distribution and marketing (25% in 1976)
  - 20.3% by incineration (35% in 1976)
  - 6.6% by ocean disposal (15% in 1976)

#13/14 11.26

COMPARATIVE RISK ASSESSMENT PROJECT

PHYSICAL ALTERATION OF AQUATIC HABITATS

I. Overview and General Conclusions

Problems #13 and #14 have been redefined by the Ecological Risk Workgroup into a single new category: "Physical alteration of Aquatic Habitats." Physical impacts to aquatic systems result from activities such as dredge and fill discharges, channelization, drainage, impoundment, mining and extraction, shoreline stabilization and silviculture and agriculture activities. Physical impacts, including direct, indirect and cumulative effects, are manifested in four general categories of the most damaging ecological effects occurring in marine, estuarine, and freshwater systems:

1. Physical Habitat Alteration or Loss,
2. Addition of Suspended Solids (including turbidity and sedimentation effects),
3. Modification of Water Levels, Flow Regimes, and Circulation Patterns, and
4. Changes to Ambient Water Parameters (e.g., O_2, CO_2 temperature, light) that result from physical alteration of aquatic systems.

Several conclusions regarding physical impacts to aquatic systems can be made:

1. Habitat loss or alteration is the most significant ecological effect associated with physical impacts to aquatic systems.
2. Wetland systems, particularly isolated, freshwater wetlands, represent the aquatic system subject to the greatest risk from physical impacts. Deep ocean systems are currently at least risk.
3. Ecological risk to rivers and streams from physical stresses is also very high, but the threats appear to be more regional in nature, with the West representing the highest risk region.
4. Among the geographic areas subject to the greatest risk from physical impacts to aquatic systems are the Bottomland Hardwood riparian wetlands of the Southeast, Prairie Pothole wetlands of the Midwest, and the tundra wetlands, rivers and near coastal zone of Alaska's North Slope. The physical threat to Bottomland Hardwood wetlands and Prairie Pothole wetlands is associated with agricultural conversion through filling and drainage activities while the threat to arctic Alaskan aquatic systems is from construction fill and gravel mining activities attendant to oil and gas exploration.

5. The development and application of regulatory controls should recognize that the effects associated with physical impacts to aquatic systems frequently involve the total elimination of ecological values and functions of a site and that these effects may be irreversible. As a result, regulation should focus on preservation of remaining aquatic systems, particularly in areas where cumulative losses are significant.

II. Description of Environmental Problem and Impacts

A. Sources of Problem and Stress Agents

The Ecological Risk Workgroup has redefined Environmental Problems #13 ("To Estuaries, Coastal Waters, and Oceans from All Sources") and #14 ("To Wetlands from All Sources") as a single new category; "Physical Alteration of Aquatic Habitats." For the purpose of evaluating ecological risk, this category is intended to cover those impacts that result from the following activities in marine, estuarine, and freshwater aquatic systems:

- Dredge Spoil Disposal
- Filling (for the purpose of creating fastland or altering bottom contours and depth)
- Channelization (including deepening, straightening, bank reconfiguration, levee construction, culverting)
- Other Dredging
- Drainage
- Shoreline Stabilization (including bulkheading and beach nourishment)
- Placement of Structures
- Impoundment
- Mining and Extraction (excluding waste disposal)
- Silviculture and Agriculture Practices

These activities represent the "sources" or "stress agents" that cause the physical alteration of aquatic habitats. Each type of activity is attended by an identifiable suite of physical impacts. In turn, each type of physical impact can be shown to induce a derived set of biological effects, occurring directly, indirectly, or cumulatively, and which are at least generally predictable. The most damaging effects to marine, estuarine, and freshwater aquatic systems are derived as a consequence of direct habitat loss or alteration, addition of suspended solids (turbidity), modification of water levels and flow regimes, and changes to ambient water conditions such as temperature, light, pH, nutrients, oxygen and carbon dioxide. Chemical impacts on the aquatic environment from anthropogenically derived pollutants including heavy metals, radioactive isotopes, and pesticides will not be considered under this category.

B. Overview of Physical Impacts

There are several generalizations regarding physical impacts to aquatic systems that, if described at this point, should help in evaluating the nature of stresses on aquatic habitats.

1. *Aquatic systems are evolutionarily adapted to the naturally prevailing suite of environmental conditions.* As a result, *aquatic systems adapted to a very narrow range of conditions* (e.g., salinity, temperature, oxygen) tend to be the most susceptible to even small introduced changes. Moreover, the most damaging impacts to any type of aquatic system are typically associated with activities that induce major or prolonged alteration of environmental norms.

2. *Natural aquatic systems are balanced at some middle range with respect to most environmental factors.* Disturbance from this state may occur through deviation at either extreme, i.e., through deficiency or excess of a given factor.

3. *Although the general effects of a given type of activity can be predicted with a reasonable level of confidence, details will vary with local circumstances.*

4. *The single most important impact of man's activities in aquatic systems is habitat alteration.* Habitat, broadly defined as "the place where an organism lives," encompasses those ecological features of an area upon which the organism (or population, or community) is dependent for survival; without these features the organism cannot survive. The habitat value of a particular area is related to the abundance and diversity of these required ecological features (e.g., cover, food sources, nesting sites, resting areas, nursery areas). Habitat requirements vary widely from species to species and, in general, the more habitat requirements (i.e., features) provided by a particular area, the greater its value and consequently, the more significant its loss.

5. The three principal types of physical impacts to aquatic resources are: 1) Direct Effects, 2) Indirect Effects, and 3) Cumulative Effects. Direct effects are caused by specific activities and occur at the same place and time as the activity. Indirect effects are impacts on an aquatic system that are associated with a particular activity, but occur later in time or are farther removed in distance. Cumulative impacts are the changes in an aquatic system that are attributable to the collective effect of a number of individual activities that are occurring concurrently or that may have occurred in the past, or that may reasonably occur in the future.

C. Scope of Physical Impacts to Aquatic Systems 1/

1. Marine and Estuarine Systems

a. Open Ocean Ecosystems

The environmental impact on deep ocean aquatic resources from physical stresses is currently considered negligible. The primary reason is that there are few activities which generate physical impacts that are now widely conducted by man in the deep ocean.

It is anticipated that as the need for mineral and energy resources increases in this country, and as the capital and technology necessary to exploit deep sea-bed resources become available, the threat to poorly studied abyssal communities will increase. Although the most significant physical threat appears to be associated with future mining and extraction activities, other potential water column and benthic physical impacts are associated with deep ocean disposal practices, increased sedimentation from rivers (particularly on the West and Gulf coasts where the continental shelf is most narrow), and military construction for defense and reconnaissance purposes.

Equilibrium conditions in the ocean, particularly at abyssal depths, are virtually constant and communities adapted to these conditions (e.g., light pressure temperature, salinity), are susceptible to even small perturbations. Future planning for activities in the deep ocean should recognize the vulnerability of this system to anthropogenic impacts.

b. Shallow Coastal Waters [Coastal Ecosystems]

For the purposes of this analysis, shallow coastal waters are defined as the submerged margins of the continent extending from the mean low water line of the coast seaward to the edge of the continental shelf (depth approximately 600 feet).

1/ For purposes of this paper, we did not strictly follow the ecosystems categories established by the expert panel since we believe that they are more properly suited to chemical (vs. physical) impacts. Where differences exist, corresponding panel categories are cross-referenced in brackets.

The Department of Commerce has estimated that by the year 2000, the United States may have more than a trillion dollars invested offshore, primarily in shallow, coastal waters. Coastal waters are utilized by man for the commercial and recreational harvest of marine fisheries and are a valuable source of numerous other products including petroleum, natural gas, sulphur, phosphates, shell, sand, and gravel, and they are important in marine transportation.

The scope of activities being conducted in shallow coastal waters is currently expanding as terrestrial sources of mineral and energy resources are exhausted. The most significant physical impact associated with man's activities in coastal waters is the loss or modification of marine habitat. The impacts tend to be localized as a consequence of the fact that mineral and energy resources of the sea-bed occur primarily in scattered, highly localized deposits and structures on top of, and within, the sediments and rocks of the ocean floor. Large scale economic exploitation has so far been confined largely to the U.S. continental shelf in waters less than 350 feet deep and within 70 miles of the coastline. Most current and near-future activities are proposed for the U.S. Gulf, West, and Alaskan coasts.

Oil and gas represent more than 90 percent by value of all minerals obtained from near-coastal waters and have the greatest potential for the future. The coastal waters of single greatest interest for oil and gas development in the U.S., and also among the most susceptible to physical impacts, are the shallow waters of Alaska's Beaufort Sea. The most economical approach to energy development in the Beaufort involves construction of gravel causeways in the shallow coastal waters to connect artificial, gravel production islands with processing and transportation facilities on land. Demonstrated impacts of this type of fill discharge in the shallow Beaufort Sea include modified circulation patterns, changes in temperature and salinity patterns, and direct loss of habitat. This construction is being shown to affect the migration patterns of numerous anadramous fishes, and the ability of these species to reach Beaufort Sea feeding and rearing areas. There is also concern regarding the effects of causeways and artificial islands on Beaufort Sea whale populations.

c. Estuaries

An estuary is the expanded mouth of a river near its entrance to the sea. The estuary extends upstream or landward to where ocean derived salts measure approximately .5 ppt and seaward to an imaginary line closing the mouth of a river, bay, or sound to the ocean. The estuary is subject to the influence of both the river and the sea, with salinity conditions ranging from nearly fresh to marine (and in some cases higher). Due to their juxtaposition between fresh and marine systems, estuaries are dynamic environments characterized by species adapted to wide ranges in ambient conditions. However, the stresses on organisms imposed by "natural" fluctuations in ambient conditions frequently make them extremely vulnerable to anthropogenic stresses to which they are not adapted.

By the year 2000, half of the estimated 312-million U.S. population will live on five percent of the land area in three coastal urban belts: the megalopolises of the Atlantic, the Pacific, and the Great Lakes. Along with the people will come an intensification of competing demands for the limited resources of the narrow, fragile coastal zone, including in particular the major coastal estuaries.

The scope of activities with potential physical impacts being conducted in estuarine waters is broad focusing principally on commercial development, port and harbor maintenance, stabilization activities and agriculture (associated non-point discharge impacts). Each of the major Atlantic, Pacific and Gulf coast estuaries is showing some degree of stress from physical impacts associated with man's activities. However, the Chesapeake estuary on the Atlantic coast and the San Francisco and Puget Sound estuaries of the Pacific coast appear currently to be among the most vulnerable to the anthropogenic stress that is accompanying increased development and utilization of these estuaries.

The following activities are the principal source of physical impacts causing observed declines in living resources in these estuaries:

1. Increased eutrophication from nutrient sources (sewage plants, agricultural runoff),

2. Disruption of estuarine food webs due to wetlands loss, increased turbidity, and sedimentation associated with dredge and fill disposal, and mining activities (sand, gravel, phosphates), and

3. Loss of estuarine habitat including seagrass beds and spawning, rearing and feeding areas as a result of dredge and fill disposal, shoreline stabilization, and development activities.

d. Tidal Wetlands [Saltwater Wetlands and Freshwater Flowing Wetlands, in part]

Tidal wetlands are lands transitional between terrestrial and aquatic systems that are subject to the ebb and flow of the tides. Tidal wetlands are generally characterized by one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophytic vegetation, 2) the substrate is predominantly undrained hydric soils, 3) the substrate is saturated with water at some time during the growing season each year. Salinity characteristics range from freshwater tidal wetlands (1 <ppt) to polysaline (18-30 ppt) and hypersaline (>40 ppt) tidal wetlands.

There is a wide range of activities impacting tidal wetlands including modification for agriculture; channelization for flood control; filling for housing, highways, industry and sanitary landfills; dredging for navigation channels, harbors and marinas; impoundment construction; timber harvest; peat mining; oil and gas extraction; phosphate mining and others.

The USFWS estimates that over half of the original tidal wetlands in the lower 48 States have been destroyed. 482,000 acres of tidal wetlands were lost during the period of the mid-50's to the mid-70's. Of these losses, approximately 56 percent resulted from dredging for marinas, canals and port development; 22 percent resulted from urbanization; 14 percent from the disposal of dredged material or from beach creation; 6 percent from the natural or man-induced transition of saltwater wetlands to freshwater wetlands; and 2 percent from agriculture.

While the national decline in tidal wetlands is dramatic, losses in particular regions and States are more startling. For example, reductions in Pacific flyway migratory waterfowl have been directly correlated to the conversion of approximately 90 percent of California's wetlands. In certain areas, coastal wetland loss-rates continue to be important despite more protective State and Federal laws. It is estimated, for example, that Louisiana continues to lose 25,000 acres of its tidal wetlands each year.

Despite historic losses of tidal wetlands in the United States, this resource is still actively sought by developers for residential and resort housing, marinas, and other development. The focus of the current and near-future loss of coastal wetlands is in the States of California, Florida, Louisiana, New Jersey and Texas (Texas is the only State that has not enacted special laws to protect coastal wetlands). Outside of Louisiana, coastal wetlands losses are directly related to population density. Urbanization has been responsible for over 90% of the loss directly attributed to physical activities.

An additional regional-scale source of hydrologic modification of coastal wetlands that is becoming a significant threat to wetlands in the Southeast is impoundment of tidal marshes for duck hunting and aquaculture. This situation represents a classic example of the conflict between preserving public resource interests and protecting the rights of private ownership. Hundreds of thousands of acres of tidal wetlands in the Southeast are in private ownership but protected under public trust. Landowners are more frequently seeking to "manage" their property for greater return without actually converting their wetlands to uplands. The solution for the landowner is to dike the wetlands into large impoundments that can be managed for hunting or aquaculture. The consequence is that thousands of acres, approximately 75,000 acres in South Carolina alone, are under threat of being impounded and isolated from the adjacent estuarine system. State and Federal laws that protect wetlands are difficult to apply in these situations because impoundments remain aquatic systems, albeit with vastly different characteristics than the marshes they replace.

EPA has identified three areas of information where more study is necessary to ensure effective and consistent wetlands protection; 1) mitigation, 2) cumulative impacts resulting from previous wetland losses, and 3) the contribution of wetlands in protecting water quality. The consistent evaluation of cumulative wetland impacts is particularly important because much of the current losses are occurring on a piecemeal basis where individual, direct impacts are small.

Future regulatory management of wetlands should focus on integrating available controls. Although Section 404 of the Clean Watger Act is helpful in controlling some types of activities in wetlands, development of water quality standards for wetlands, non-point source pollution controls, and other regulatory controls that can be applied in an integrated approach would contribute to more effective regulation of wetlands.

2. Freshwater Systems

a. Rivers and Streams [Buffered and Unbuffered Streams]

Rivers and streams are lotic freshwater systems with directional flow and which drain water from the continent to the ocean. They are extremely diverse ecosystems which are typically susceptible to even small environmental perturbations, such as changes in turbidity, flow, temperature, light, dissolved oxygen and substrate.

Man continues to physically modify and impact rivers and streams on a national scale for flood control, transportation, urban construction, agriculture, recreation, hydroelectric power, water supply, mining activities, and other purposes. Recognizing the functions and values of rivers and streams for recreational and commercial purposes, local, State, and Federal laws are becoming increasingly effective in protecting these systems. However, in specific areas, conflicting regional needs are resulting in significant hydrologic modifications of rivers and streams.

In the water-scarce West and Southwest, natural water courses are being channelized, diverted, and impounded to satisfy agricultural and commercial users to the detriment of the environment. Placer mining in Alaska and the Northwest is being carried out in stream beds, flood plains, and river banks in search of gold and other minerals. This type of hydraulic mining requires enormous quantities of water for digging and processing (up to 32,000 gal/cubic yard). These operations destroy stream beds and alluvial valley soils, and produce tremendous quantities of gravels, sands, and fine silts, which enter streams creating turbidity and sedimentation problems. Flood control/irrigation/hydroelectric projects continue to eliminate riparian habitat, increase water temperature and turbidity, and alter normal circulation patterns. The Garrison Diversion Project in North Dakota, for example, continues despite recognized regional concerns regarding loss of critical riparian habitat.

b. Lakes

Lakes are lentic systems characterized by a large open water (limnetic) zone compared with the extent of the shallow water (littoral) zone. The "producing" region in lakes (region where light energy is fixed by phytoplankton into food) is in the limnetic zone. Thus, it is this limnetic zone and the nature of the bottom and its biota that are of the greatest interest in assessing potential impacts to lake environments.

Most of the physical impacts to lakes result from modification of the littoral zone. These activities include bulkheading, filling for recreational and commercial purposes, shoreline stabilization, and agriculture and silviculture practices occurring on the lake margin. Because the critical region in lakes (limnetic zone) is generally not directly impacted by these activities (although frequently numerous), the overall environmental impact rating is considered medium (Impacts to the vegetated littoral areas (i.e., wetlands) is properly considered in the next section).

The major environmental concern to lake environments results from chemical and subsequent biological modification of lakes rather than from physical impacts. This is particularly true for lakes in the Northeast where the natural buffering capacity is being affected by acid rain. There does not appear to be a significant large scale problem associated with physical impacts to lakes in this country. However, in specific instances where lake environments are being altered significantly by such activities as dredge spoil disposal, filling, and other activities, it may represent an important local problem, particularly where the littoral zone provides important aquatic habitat.

c. Freshwater Wetlands (Non-Tidal) [Buffered and Unbuffered Freshwater Isolated Wetlands and Freshwater Flowing Wetlands, in part]

Freshwater wetlands are similar to tidal wetlands but most importantly do not receive the energy subsidy associated with the ebb and flow of the tides. Examples include riparian wetlands along the shores of rivers and streams, swamps, bogs, pocosins and fens.

Perhaps the most significant, large-scale hydrologic modification occurring in this country today is the physical alteration and loss of inland, freshwater wetlands. Historic and current loss rates are tremendous and have produced significant adverse environmental impacts to many regions of the U.S. Ninety-seven percent of all wetland losses have occurred in freshwater wetlands. The USFWS estimates that 11 million acres of freshwater wetlands were lost from the mid-50's through the mid-70's and that the loss rate continues at approximately 350,000-400,000 acres per year. Agricultural conversions involving drainage, clearing, land leveling, groundwater pumping and surface water diversion were responsible for 80 percent of the observed conversion. Of the remainder, 8 percent resulted from the construction of impoundments, 6 percent from urbanization, and 6 percent from other causes such as mining, forestry, and road construction. Fifty-three percent of these conversions occurred in forested areas, such as bottomlands.

Losses of freshwater wetlands have been observed nationwide. Less than 5% of Iowa's natural wetlands remain and over 90% of the critical central flyway wetlands of Nebraska's Rainwater Basin have been destroyed. Only 20% of the original bottomland hardwood forests in the Lower Mississippi Alluvial Plain remain. Other States with less than half of their original freshwater wetlands include Michigan, Minnesota, Louisiana, North Dakota, Connecticut, Ohio, Indiana and Illinois.

The trend of freshwater wetlands losses continues despite recent State and Federal laws that are designed primarily to protect coastal wetlands. Bottomland Hardwood wetlands of the Lower Mississippi Alluvial Plain are being converted at an estimated 165,000 acres per year. Louisiana is losing its forested wetlands at a rate of 87,000 acres per year. Pocosin wetlands of North Carolina are being destroyed at a rate of 44,000 acres a year and prairie potholes of the upper midwest are being lost at nearly 33,000 acres a year. In each case, the wetlands are being lost primarily for agricultural purposes.

An additional area of concern regarding hydrological modification of freshwater wetlands is in tundra wetlands of Alaska's North Slope. These pristine, highly valuable wetlands cover an area the size of California and serve as critical breeding grounds for numerous species of waterfowl each year. Oil and gas development activities proliferating on the North Slope represent a significant threat to this important wildlife habitat. Gravel roads, drill pads, production facilities, pipelines, housing, power stations and most other facilities constructed on the fragile tundra require placement on gravel insulation 3-5 feet thick. The necessary mining and fill activities associated with this construction represent a significant threat to extremely vulnerable tundra wetland ecosystems.

While predicting the future of the Nation's freshwater wetlands is extremely difficult and complex, an examination of recent trends in population, agriculture, and wetland protection provides some insight into what can be expected. Population growth and distribution and agricultural development greatly affect land-use patterns which impact wetlands. Government's wetland protection efforts are key to preserving wetland functions and values for today's public and future generations.

3. Terrestrial Systems

Although, by definition, this "Environmental Problem" has been effectively limited to aquatic systems, two important points must be noted.

a. In the natural world there are generally no sharp boundaries between aquatic and terrestrial ecosystems. In many, if not the majority of, cases aquatic systems are closely linked to adjacent terrestrial systems through food chains, chemical cycles, the movement of animals, etc. Accordingly impacts on one may have significant, perhaps profound, impacts on the other. As an example, the elimination through filling or draining of a small wetland or pond in an arid area would eliminate the only source of water for many terrestrial birds and mammals and, hence, eliminate their local populations. A more subtle example would be the impact on a brown bear population of reduction or loss of appropriate salmon habitat in a stream or river. These sorts of effects will generally be most pronounced in areas where fresh water is limiting (e.g., western riparian, desert, barrier islands) or where there is a high degree of interspersion between aquatic and terrestrial habitats) (e.g., tundra, intertidal zone, bottomland hardwood forests).

b. Significant physical changes to aquatic systems may produce important secondary or indirect physical impacts on adjacent terrestrial areas. These include inundation (from impoundment), flooding (from stream modification or wetlands loss), loss of water supply (from filling of wetlands serving as groundwater recharge areas or stream modification), or changes in micro-or meso-climate (from elimination of wetlands and/or lakes). Similarly, certain hydrological modifications such as impoundment can induce major human development which can have substantial impact on terrestrial ecosystems.

D. EPA Regulatory and Other Authorities

1. Clean Water Act

a. Section 404. Requires permits for the discharge of dredged material ("spoil") or upland-derived fill. Does not directly control drainage, timbering, or other agricultural activities except where there is incidental discharge of dredge or fill material. Program is fairly effective in controlling regulated activities, particularly in coastal areas. As much as 75% of U.S. wetlands loss may be outside the reach of the program.

b. Water Quality Management/Nonpoint Source programs. Principally state/local programs that range from advisory-financial support to true regulatory programs. Such programs, when effectively implemented, can provide an important handle on certain activities (through water quality certification) and can help control nonpoint source pollution with its direct (siltration) and indirect (necessity for dredging) impacts.

c. Estuaries Program. Through comprehensive planning and financial support, this program may come to have a marked effect on hydrological modifications, at least in the Nation's major estuaries.

2. Marine Protection, Research & Sanctuaries Act

Title 1 requires permits for ocean dumping of any pollutant. This is the only such requirement and provides an effective regulatory handle on discharges that may significantly change bottom contours and perhaps currents.

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3. Clean Air Act

Section 309 authorizes EPA to review and comment on all federal projects and actions, including environmental assessments/impact statements, policies, regulations, and program plans. Through this activity EPA can significantly influence a wide variety of federal activities that involve hydrologic modifications. Such activities range from the construction of highways and housing developments to land management on all federal lands (forests, parks, BLM lands, etc.)

4. National Environmental Policy Act

NEPA requires EPA, like any other federal agency, to evaluate the environmental impacts of its actions and to seek to reduce those impacts. As the result of a number of statutory and judicial exemptions, NEPA is applied rather narrowly within EPA, but for those activities where it is applied--principally construction grants for sewage treatment plants and NPDES permits for new source industries--it plays an important role in avoiding or minimizing physical impacts to aquatic systems.

IV. Evaluation of Problem

Table 1 (page 13) presents a matrix which assigns a risk assessment rating by comparing the four generalized ecological impacts with each of the seven classes of aquatic systems. The matrix is derived by fitting the information summarized in Sections II and III of this paper into the "Ecological Risk Model" developed by the workgroup. A consideration of the matrix can provide a series of general conclusions regarding the risks from physical alteration of aquatic systems; these are presented in Section I.

Gregory E. Peck
Office of Wetlands Protection

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Office of Federal Activities

November 20, 1986

TABLE 1

MATRIX FOR PHYSICAL AQUATIC IMPACTS

	Marine & Estuarine Systems				Freshwater Systems		
	Deep Ocean	Shallow Coastal Waters	Estuaries	Tidal Wetlands	Rivers and Streams	Lakes	Non-Tidal Wetlands
Physical Habitat Loss or Alteration	-	M_R	H_R	H_N	H_E	H_E	H_N
Addition of Suspended Solids (Turbidity)	-	H_N	M_R	M_R	H_N	L_R	M_R
Modification of Water Levels and Flow Regimes	-	M_R	H_R	H_N	H_R	M_E	H_N
Changes to Ambient Water Parameters (e.g. O_2, CO_2, temperature, light) as a result of physical alteration	-	L_R	H_R	H_N	H_R	M_E	H_N
Overall Impact Rating	-	M_R	H_R	H_N	H_R	M_E	H_N

E = Ecosystem-Wide effects
R = Region-Wide Effects
N = Nationwide Effects

SCALE - H = High
M = Medium
L = Low
- = Imperceptible Ecological Effect

Appendix
Information Sources

1. Darnell, R. M., *et. al.*, 1976, Impacts of Construction Activities in Wetlands of the United States, U.S.E.P.A., Ecological Research Series #EPA-600/3-76-045, 393 p.
2. Tiner, R. W., 1984, Wetlands of the United States: Current Status and Recent Trends, USFWS, 59 p.
3. Cowardin, L. M., *et. al.*, 1979, Classification of Wetlands and Deepwater Habitats of the United States, USFWS Biological Services Program, FWS/OBS-79/31, 103 p.
4. Wetzel, R. G., 1975, Limnology, W. B. Saunders Co., 743 p.
5. Wetlands: Their Use and Regulation, 1984, U.S. Congress, Office of Technology Assessment, OTA-O-206, 208 p.
6. Adamus, P. R. and L. T. Stockwell, 1983, A method for Wetland Functional Assessment, FHWA-IP-82-23, 176 p.
7. Oceanography, 1971, Scientific American, W. H. Freeman Co., 417 p.
8. Section 404(b)(1) Guidelines, December 24, 1980, USEPA, 40 CFR Part 230, *Federal Register*, Vol. 45, No. 249, p. 85336.

SUMMARY #16

Hazardous Waste Sites - Active
(Subtitle C Waste Management Facilities)

Sources: 2,863 Treatment and Disposal Facilities for RCRA Hazardous Wastes including thermal treatment units, land disposal units, recycling units, and other chemical, biological, or physical treatment units.

Exposure: Routine releases of particulates, toxics, and/or nutrients to air, surface water, and/or soil over facility lifetime.

Location: Facilities are located in a variety of environmental settings--this problem area includes onsite units, as well as commercial units.

Ecosystem Impacts: Localized impacts, potentially reversible over a 10 year period.

Controls: In place or planned.

Workgroup Ranking: Low

HAZARDOUS WASTE SITES - ACTIVE
(Subtitle C Waste Management Facilities)

I. Description of Sources

Chemicals (some considered "exotic") at Subtitle C Waste Management facilities may contribute directly and indirectly to the degradation of ecosystems. They can directly effect an ecosystem by being discharged into surface water via aqueous waste treatment facilities, air pollution control devices on incinerators and distillation facilities, and runoff. Indirectly, they can enter surface water via groundwater flowing beneath land disposal facilities.

In addition, contamination of soils from point and area source emissions at some facility locations may also adversely affect vulnerable plant and animal habitats. This may also result from spills occurring during product/waste transfer.

Two other "ecological" or welfare problem areas are important, but not within the current scope of OPPE's Comparative Risk Project: the net loss of available land, and the net loss of available groundwater that may be associated with hazardous waste management activities.

The releases discussed above can result from either routine or non-routine activities at waste management facilities. These releases could increase the concentrations of various chemicals in water, in air, and on land to levels that threaten the productivity of receiving ecosystems, increasing the risk to vulnerable species.

The market for waste management facilities exists in a variety of locations, irrespective of environmental setting. When these facilities are built, efforts are usually made to assure that technology and operating requirements will prevent groundwater contamination regardless of setting. Facilities are currently operating in almost every type of setting. Thus, releases from hazardous waste management facilities, both commercial and onsite, may affect both buffered and unbuffered lakes and streams, forests, grasslands, marine and estuarine ecosystems, and in a few cases, desert and tundra environments.

Ecological effects may occur in natural regions (not EPA regions) or be limited to specific ecosystems. Even a catastrophic event at a waste management facility would not be expected to produce impacts that are biospheric, or global, in scale.

II. Detailed Description of Sources

There are 2,863 active hazardous waste management facilities, excluding storage facilities. These facilities can be broken down into four broad categories: thermal treatment facilities, land disposal facilities, solvent recovery facilities, and other types of treatment facilities. The chart on the next page shows for each broad treatment category the number of facilities in that category, the major stress agents produced, the fate of releases, duration of exposure and frequency of exposure.

SUBTITLE C WASTE MANAGEMENT FACILITIES

Facility Type	#Facilities	Major Stress Agent	Fate of Releases: Air	Fate of Releases: Surface Water	Fate of Releases: Soil*	Duration of Potential Exposure	Frequency of Potential Exposure
Thermal Treatment	298	Particulates Toxics	X X	X X	X X	Facility Lifetime	Routine
Land Disposal	433	Toxics	X	X	X	Facility Lifetime	Routine
Recycling	846	Toxics	X	X	X	Facility Lifetime	Routine
Treatment	1286	Toxics Nutrients	X	X X	X	Facility Lifetime	Routine

*From air deposition and spills

III. Evaluation of Ecological Risk

At this point in time, it is impossible to calculate the absolute ecological risk attributable to hazardous waste management facilities. However, a high, medium, or low ranking can be assigned by estimating if the major stress agents (toxics, particulates, and nutrients) could affect each of several ecosystems and how severe any of the impacts might be. The scoring for Subtitle C waste management facilities is shown here:

Subtitle C Waste Management Facilities

Major Stress Agents: Toxics, Particulates, Nutrients
Fate of Releases: Air, Surface Water, Soil
Recovery Time for Impacts: Decades
Controls: In Place or Planned

Ecosystem	Impact
Buffered Lake	Low
Unbuffered Lake***	Medium
Buffered Stream	Low
Unbuffered Stream***	Medium
Coastal	Low
Ocean	N/A
Estuary	Low
Coniferous Forest	Low
Deciduous Forest***	Low
Grassland	Low
Desert	Low
Tundra***	Medium
Wetland - Freshwater, Isolated, Buffered***	Low
Wetland - Freshwater, Isolated, Unbuffered***	Medium
Wetland - Freshwater, Flowing	Low
Wetland - Saltwater	Low

***Most severe around thermal treatment facilities

OVERALL RANKING: Low

Environmental Problem: Superfund Sites (#17)

Potential ecological effects at Superfund sites are difficult to characterize because of lack of information. Virtually all of the chemicals frequently found at Superfund sites have acute or chronic effects on aquatic organisms. However, the concentrations at which these chemical are likely to occur and the concentrations to which aquatic organisms are likely to be exposed are not known for most sites. The likely effects of the complex mixtures of chemicals typically found at sites also are not known.

It is likely that some ecological effects occur at all sites because of the type of chemicals present, though effects at most sites probably are minor. Information from a small survey indicates that effects significant enough to affect commercial and recreational activities may be present at about 70 sites and significant ecological injuries may be present at another 200 sites. In the absence of cleanup efforts, the environment could be affected for a long time because of the size of the sources of contamination and because many of the chemicals involved are persistent and bioaccumulative.

Environmental Problem: 17, Superfund Sites

I. Description of Sources

A variety of contaminants at abandoned waste sites could have localized effects in ecosystems, especially if such contaminants migrate to surface water bodies through surface water runoff or through discharge of contaminated ground water into surface water. Effects could be regional in scope depending on the quantity and toxicity of the contaminants and the migration of such cantaminants in surface water systems.

The Superfund program has been oriented to assessing and dealing with threats to human health. Little attention has as yet been paid to assessing the environmental effects of contaminants at Superfund sites. In view of the paucity of data on the extent of environmental impacts, only general information will be provided that may give some indication of the severity of ecological effects from abandoned waste sites.

II. Detailed Description of Sources, Releases, and Exposures

Currently there are 888 sites on the National Priority List (NPL). About 75 percent of these sites involve ground water contamination and about 45 percent involve surface water contamination. (Contaminated groundwater may affect surface water bodies if the ground water eventually discharges to it in high enough concentrations.) Another 23,000 sites are on the CERCLIS list and are undergoing preliminary screening. As much as a quarter of such sites eventually could be classified as NPL sites.

An indication of the frequency with which certain chemicals are present at sites is provided in the table below. The 30 most frequently observed chemical are listed along with the percentage of sites at which they were observed (the data are based on a survey of about 540 sites).

Most Frequently Observed Chemicals (preliminary)

Chemical Name	Frequency	Chemical Name	Frequency
TCE	55%	Dichloroethylene	19
Lead	51	Copper & Compounds	19
Toluene	43	Methylene Chloride	17
Chromium & Compounds	38	Cyanides	14
Benzene	38	1,1Dichloroethene	14
Chloroform	32	Mercury	13
PCBs	29	Dichchorethane	13
Tetrachlorethene	27	Vinyl Chloride	12
Trichloroethane	26	1,2Dichlorethane	12
Zinc & compounds	25	Chlorobenzene	12
Arsenic	24	Nickel & Compounds	11
Cadmium	24	Carbon Tetrachloride	11
Phenal	22	Pentachlorophenal	10
Ethylbenzene	20	Napthalene	9
Xylene	20	Methyl ethyl ketone	7

Virtually all of these chemicals have acute or chronic effects on aquatic organisms. However, the concentrations with which these chemicals are likely to occur at sites and the concentrations to which aquatic organisms are likely to be exposed are not known for most sites. (We have not attempted to tabulate concentration and exposure data for those sites that have been sampled extensively.) The data also indicate that multiple chemicals are present at sites. The likely combined effects of mixtures of such compounds simply are not known.

No comprehensive study of ecological impacts around Superfund sites has yet been conducted. The program is only now beginning efforts to undertake bioassay assessments. Such tests are being pursued at a small number of sites (New Bedford Harbor, Commencement Bay, and OMC). However, a survey was conducted by OPA to determine the potential for natural resources injury around NPL sites (277 sites were contained in the survey). Natural resource injury was defined to exclude injuries to ground water, drinking water supplies, and air but to include all other natural resources, including surface water, wetlands, fisheries, biota, and wildlife.

Based on the survey results, about 6 percent of NPL sites are likely to have significant natural resource injuries--commercial effects (primarily to fisheries) or recreational effects large enough bring damage suits. Another 16 percent may have some possibility of injury to natural resources. The frequency with which potential ecological injuries were mention for the latter sites was as follows: surface water -- 90%; wetland -- 37%; fisheries -- 55%; and other (land, forests, endangered species, marine mammals, biota, and wilderness) -- 32%. About a third more sites with the potential for natural resouce injury may come from non-NPL sites. Thus, about 70 sites would have significant natural resource injuries and significant ecological effects may be present at another 200 sites.

Some examples of sites at which there could be significant ecological impacts are as follows:

OMC; Waukegan, IL.	-- substantial PCB contamination of harbor and river leading to Lake Michigan;
GE; Hudson River	-- significant amounts of PCBs in river sediments;
Whitewood Creek, SD and Phelps Dodge, AZ	-- aquatic damage due to metals contamination from mining wates;
Nashua, NH	— ground water contaminated with volatile organics discharging into swamp and nearby river;
Mottalo, NH	-- swamps, creek and river adjacent to site
Waste Industries, SC	-- estuarine swamp land and nesting birds threatened by leaking municipal waste site;
New Bedford, Habor	-- significant PCB contanination of harbor; and
Hyde Park Landfill	-- site contains over 1 ton of dioxins; low concentrations in ground water discharging to the Niagra river and thence to Lake Ontario.

Unfortunately, studies are not available to assess the actual effects of contamination on the ecology at these sites. For instance, in New Bedford

Harbor high levels of PCBs have been found in the tissues of marine organisms, but no information is yet available on whether the community structure, reproductive cycles of longevity of species has been affected.

III. Evaluation of the Problem

It is difficult to characterize potential ecological effects at Superfund sites because of the lack of data. Given the nature of the chemicals present at such sites, it is likely that some ecological effects occur at all sites, though at most sites they probably are minor. However, based on very preliminary information effects significant enough to affect commerical and recreational activities may be present at about 70 sites and significant ecological injuries may be present at another 200 sites. Many of the chemicals involved are persistent and bioaccumulative and could affect the environment for extended periods of time.

Sources of information:

Putnam, Hayes & Partlett, Inc., Assessment of the Potential for Natural Resource Claims at Hazardous Waste Sites, Sept. 1985

SUMMARY #18

Municipal "Non-Hazardous" Waste Sites - Active
(Subtitle D Municipal Waste Management Facilities)

Sources: 16,636 Treatment and Disposal Facilities for RCRA "Non-Hazardous" Municipal Wastes including thermal treatment units, landfills, surface impoundments and land application units.

Exposure: Routine releases of particulates, toxics, BOD, microbes, PCDFs, PCDDs, and/or nutrients to air, surface water, and/or soil over facility lifetime.

Location: Facilities are located in many locations, encompassing many different environmental settings.

Ecosystem Impacts: Localized impacts, potentially reversible over a 10 year period.

Controls: Not much.

Workgroup Ranking: Medium

MUNICIPAL "NON-HAZARDOUS" WASTE SITES - ACTIVE
(Subtitle D Municipal Waste Management Facilities)

I. Description of Sources

Chemicals from municipal waste management facilities may contribute directly and indirectly to the degradation of surrounding ecosystems primarily via surface water and air routes. They can be directly discharged via surface water runoff and through covolatilization during methane generation and emission. Indirectly, they can enter surface water via groundwater flowing beneath land disposal facilities.

Another potential problem area is the use of municipal waste combustion fly ash for fill in surface water bodies. It is not clear how often this takes place, but some ash has been found to contain polychlorinated dibenzofurans and dioxins (PCDFs and PCDDs). These substances are thought to be highly toxic to aquatic life.

Two other "ecological" or welfare problem areas are important, but not within the current scope of OPPE's Comparative Risk Project: the net loss of available land and the net loss of available groundwater that may be associated with waste management activities.

The releases discussed here can result from routine activities at municipal waste management facilities. These releases could increase the concentrations of various chemicals in water and on land to levels that threaten the productivity of receiving ecosystems, increasing the risk to vulnerable species.

Municipal waste management facilities of some type are located in virtually every community in the nation, in every type of environmental setting. When these facilities are built, efforts are made to assure that technology and operating requirements will prevent groundwater contamination regardless of setting. Facilities are currently operating in almost every type of setting. Thus, releases from municipal waste management facilities may affect both buffered and unbuffered lakes and streams, forests, grasslands, marine and estuarine ecosystems, and in desert and tundra environments.

Ecological effects may occur in natural regions (not EPA administrative regions) or may be limited to specific ecosystems. Even a catastrophic event at a waste management facility would not be expected to produce impacts that are biospheric, or global, in scale.

II. Detailed Description of Sources

There are 16,636 active municipal waste management facilities, These facilities can be broken down into four broad categories: landfills, surface impoundments, land application units, and incinerators. The chart on the next page shows for each broad treatment category the number of facilities in that category, the major stress agents produced, the fate of releases, duration of exposure and frequency of exposure.

SUBTITLE D MUNICIPAL FACILITIES

Facility Type	#Facilities	Major Stress Agents	Fate of Releases Air	Fate of Releases Surface Water	Fate of Releases Soil	Duration of Potential Exposure	Frequency of Potential Exposure
Landfills	9,280	BOD		X		Facility Lifetime	Routine
		Nutrients		X			
		Microbes		X			
		Toxics	X	X	X		
Surface Impoundments	2,426	BOD		X		Facility Lifetime	Routine
		Nutrients		X			
		Microbes		X			
		Toxics	X	X	X		
Land Application Units	11,937	BOD				Facility Lifetime	Routine
		Microbes					
		Toxics	X	X	X*		
		Nutrients					
Incinerators	110	Particulates	X	X	X	Facility Lifetime	Routine
		Toxics	X	X	X		
		PCDF, PCDD	X	X	X		

*From direct application as opposed to air deposition and spills.

III. Evaluation of Ecological Risk

At this point in time, it is impossible to calculate the absolute ecological risk attributable to municipal waste management facilities. However, a high, medium or low ranking can be assigned by estimating if the major stress agents (BOD, nutrients, microbes, toxics, particulates, PCDFs and PCDDs) could affect each of several ecosystems and how severe any of the impacts might be. The scoring for Subtitle D municipal waste management facilities is shown here:

Subtitle D Municipal Waste Management Facilities

Major Stress Agents: BOD, nutrients, microbes, toxics particulates, PCDFs and PCDDs
Fate of Releases: Air, Surface Water, Soil
Recovery Time for Impacts: Years
Controls: Not Very Controlled

Ecosystem	Impact
Buffered Lake	Medium
Unbuffered Lake*	Medium
Buffered Stream	Medium
Unbuffered Stream*	Medium
Coastal	Low
Ocean	N/A
Estuary	Low
Coniferous Forest	Low
Deciduous Forest*	Medium
Grassland	Medium
Desert	Medium
Tundra*	High
Wetland - Freshwater, Isolated, Buffered*	Medium
Wetland - Freshwater, Isolated, Unbuffered*	High
Wetland - Freshwater, Flowing	Low
Wetland - Saltwater	Medium

*Most severe around municipal waste incinerators

OVERALL RANKING: Medium

SUMMARY #19

Industrial "Non-Hazardous" Waste Sites - Active
(Subtitle D Industrial Waste Management Facilities)

Sources:	193,484 Treatment and Disposal Facilities for RCRA "Non-Hazardous" Wastes including thermal treatment units, landfills, surface impoundments and land application units.
Exposure:	Routine releases of particulates, toxics, BOD, and/or nutrients to air, surface water, and/or soil over facility lifetime.
Location:	Facilities are located in many locations, encompassing many different environmental settings, and many times several are located in the same area.
Ecosystem Impacts:	Localized impacts, potentially reversible over a 10 year period.
Controls:	Some
Workgroup Ranking:	Medium

INDUSTRIAL "NON-HAZARDOUS" WASTE SITES - ACTIVE
(Subtitle D Industrial Waste Management Facilities)

I. Description of Sources

Chemicals from non-hazardous industrial waste management facilities may contribute directly and indirectly to the degradation of surrounding ecosystems primarily via surface water and air routes. They can be directly discharged from the solid waste management unit and via surface runoff. Indirectly, they enter surface water via groundwater flowing beneath land disposal facilities.

In addition, contamination of soils from point and area source air emissions at some facility locations may also adversely affect vulnerable plant and animal habitats. This may also result from spills occurring during product/waste transfer.

Two other "ecological" or welfare problem areas are important, but not within the current scope of OPPE's Comparative Risk Project: the net loss of available land and the net loss of available groundwater that may result from industrial waste management activities.

The releases discussed here can result from both routine and non-routine activities at waste management facilities. These releases could increase the concentrations of various chemicals in water and on land to levels that threaten the productivity of recieving ecosystems, increasing the risk to vulnerable species.

Industrial waste management facilities exist at many locations, irrespective of environmental setting. When facilities are built, it is hoped that efforts will be made to assure that technology and operating requirements will prevent groundwater contamination regardless of setting. Facilities currently operate wherever industry operates, in almost every type of setting. Thus, releases from industrial waste management facilities may affect both buffered and unbuffered lakes and streams, forests, grasslands, marine and estuaring ecosystems, and in a few cases, desert and tundra environments.

Ecological effects may occur in natural regions (not EPA administrative regions) or be limited to specific ecosystems. Even a catastrophic event at a waste management facility would not be expected to produce impacts that are biospheric, or global, in scale.

II. Detailed Description of Sources

There are 193,484 active industrial waste management facilities. These facilities can be broken down into four broad categories: landfills, surface impoundments, land application units, and incinerators. The chart on the next page shows for each broad treatment category the number of facilities in that category, the major stress agents produced, the fate of releases, duration of exposure and frequency of exposure.

SUBTITLE D INDUSTRIAL FACILITIES

Facility Type	#Facilities	Major Stress Agents	Fate of Releases			Duration of Exposure	Frequency of Exposure
			Air	Surface Water	Soil		
Landfill	7,136	Toxics BOD Nutrients	X	X X X	X X X	Facility Lifetime	Routine
Surface Impoundments	189,396	Toxics BOD Nutrients	X	X X X	X X X	Facility Lifetime	Routine
Land Application Units	6,952	Toxics	X	X	X*	Facility Lifetime	Routine
Incinerators	UNKNOWN	Toxics Particulates	X X	X X	X X	Facility Lifetime	Routine

*From direct application as opposed to air deposition or spills.

III. Evaluation of Ecological Risk

At this point in time, it is impossible to calculate the absolute ecological risk attributable to industrial waste management facilities. However, a high, medium or low ranking can be assigned by estimating if the major stress agents (BOD, nutrients, toxics, particulates) could affect each of several ecosystems and how severe any of the impacts might be. The scoring for Subtitle D industrial waste management facilities is shown here:

Subtitle D Industrial Waste Management Facilities

Major Stress Agents: BOD, nutrients, toxics, particulates,
Fate of Releases: Air, Surface Water, Soil
Recovery Time for Impacts: Years
Controls: Some Controls

Ecosystem	Impact
Buffered Lake	Low
Unbuffered Lake*	Medium
Buffered Stream	Low
Unbuffered Stream*	Medium
Coastal	Low
Ocean	N/A
Estuary	Low
Coniferous Forest	Low
Deciduous Forest*	Medium
Grassland	Medium
Desert	Low
Tundra*	Low
Wetland - Freshwater, Isolated, Buffered*	Low
Wetland - Freshwater, Isolated, Unbuffered*	Medium
Wetland - Freshwater, Flowing	Low
Wetland - Saltwater	Low

*Most severe around industrial waste incinerators

OVERALL RANKING: Medium

Resource Extraction, Beneficiation and Wastes #20

Summary

Resource extraction has been ranked third along with the general area of habitat modification. This is due not only to the national distribution of the problems, but also the irreversible qualities of disturbances and their associated pollutants.

Geographical Extent:

Acid mine drainage is a result of the oxidation of metalic pyrites, which are compounds of sulfur and are ubiquitous as well as highly reactive chemically. It is most widely spread in the coal fields in the states east of the Mississippi. However, it is not unknown in the mining areas of the Rockies and in California and Alaska.

Oil and gas drilling has the greatest impact in the wetland areas of the Gulf Coast states and in Alaska as well as along the California coast. Some problems have also been recognized in land, especially where salt discharges to streams and wetlands have occurred in Appalachia. In addition, some hazardous wastes are associated with oil and gas drilling operations.

Non-energy minerals extraction problems are identified with copper mining in Arizona, Utah, and Montana. Iron mining also has caused some problems, mainly in the Lake Superior area. Phosphorus mining, mostly in Flordia (with a little in North Carolina and New Jersey) is expected to disturb close to 20,000 areas within the next 20 to 50 years.

Characteristics:

Acid mine drainage results in lowered pH of streams and high levels of dissolved minerals, especially iron and managanese. In addition, extraction, beneficiation, and reclamation result in the release of suspended solids.

Oil and gas drilling result in drastic hydrologic disturbances due to the canals and causeways that are build to access drilling sites. Drilling also produces muds and rock fines that have water pollutant impacts.

Non-energy minerals extraction generally is characterized by habitat losses, air pollution, and the release of suspended and dissolved solids to waterways. Waste byproducts are sometimes caustic, but are always voluminous, making disposal a landfill problem of large magnitude in acreage alone.

Effects/Impacts:

Acid mine drainage impacts aquatic, wetland, and terrestrial habitats. Few if any streams have returned to pre-mine quality after mining is done, Wetlands and terrestrial habitats are both chemically and physically altered by mining activities and also never return to their pre-mine quality.

Oil and gas drilling results in the annual loss of about 50,000 acreas of coastal Wetlands. Runoff patterns are irreversibly altered so that habitats are permanently changed. These losses are a direct result of canal building and channelization. Dredge and fill operations also release dissolved and suspended solids as pollutants.

Non-energy minerals extraction involve the commitment of large areas of land, usually terrestrial habitat, to mining and tailinge disposal activities. In addition, beneficiation results in wide areas imapcted by air emissions. Dissolved suspended solids are the major water pollutants and cannot be completely controlled under current technology, with the result that many thousands of miles of streams and acreas of wetlands are permanently impacted.

Abstract #20

The ecological impacts of resource extraction are felt in all four major ecological systems enumerated by the ERC Workshop and the Ecological Effects Matrix. Impacts are attributable to the nine major stress agents listed below with variations among the ecosystems with regard to the stress agents.

Stress Agents:

- Acid Mine Drainage
- Toxic Inorganic Chemicals
- Nutrients
- Turbidity
- Oils
  - Machinery
  - Spills
- Solids
  - Mine spoil
  - Beneficiation & Refining Wastes
  - Use-Byproducts
- Habitat Alteration
  - Canals
  - Causeways
  - Channelization & Dradging
- Groundwater
  - Disruption
  - Contamination

Impacts to Ecosystems:

- Acid mine drainage impacts freshwater, terrestrial, and wetland ecosystems, but is of negligible importance in marine/estuarine systems.
- Toxic inorganic chemicals are important in freshwater and terrestrial ecosystems, but appear to be of only moderate importance in wetlands and marine, and estuarine systems.
- Nutrients have high impacts in freshwater systems, but are generally of moderate importance in others.
- Turbidity is mainly a problem in freshwater systems, but only of moderate importance in marine/estuarine and, apparently, wetland habitats; it is of negligible importance in terrestrial ecosystems.
- Oils appear to be a major problem only in marine/estuarine systems.
- Solids are a problem in freshwater, wetlands, and terrestrial systems, but only of moderate importance in marine/estuarine systems.
- Habitat modification is considered to be a serious matter in all systems.
- Groundwater is seriously impacted only in freshwater and terrestrial systems and is moderately affected in wetland systems; it is neglibly impacted in the marine/estuarine systems.

It is estimated that more than 15,000 NPDES permits and about 1000 CWA Sect. 10/404 dredge and fill permits, associated with resource extraction, are in effect.

Introduction:

The United States is blessed with an abundance of natural resources which have contributed to the Nation's economic well being. However, extraction, refinement and consumption of these resources have also resulted in some of the most severe ecological problems of the country. Ecological degradation resulting from resource extraction is perhaps the most widespread form of pollution in an industrialized society. Extraction and processing of natural resources have resulted in millions of acres of surface lands permanently scarred as well as disruption and degradation of surface and underground hydrological resources. Since 1939, surface disruption for mining has affected an area equal to 2/3 the size of Connecticut. Few activities of man have the potential for adverse impacts to the ecosystem as that represented by resource extraction. The following are three areas of major concern:

- Air pollution from refining ores and crude oils.
- Land scarred by mining and reclamation methods as well as from waste products (tailings) from refinement.
- Water pollution by dissolved and suspended solids from extraction, refining, tailings disposal, and reclamation.

A wide range of aquatic, marine/estuarine, and terrestrial ecological impacts are still being identified. Habitat fragmentation caused by oil and gas extraction in Alaska and the Gulf States is one example. Groundwater disruption and degradation from resource extraction is also widespread.

In all examples of resource extraction, disturbance of the existing geological equilibrium results in ecological impacts that are difficult to evaluate in terms of long term costs. However, aggregate figures demonstrate lands lost to production, terrestrial habitat, and miles of streams degraded. Full economic and ecological analyses, however, have yet to be carried out.

Table 1: Summary Statistics on Resource Extraction.

Resource Commodity Category	Commodity Retrieved by Extraction Method		
	Surface*	Deep*	Drilling/Pumping
Metals:	1700	88	
Non-metals:	2680	78	
Energy:			
Coal:	482.7	301.2	
Gas:			19.0 million Cu. Ft.
Oil:			24.5 million BBl.

*Million Short Tons

NPDES Permits	
Coal:	10,375
Ore Mining:	515
Assoc. Ind.:	4288
Total	15,168

Energy Resources

Four states lead the Nation in oil and gas production:

1	Texas	3	Louisiana
2	Alaska	4	California

These four states produce more than three-quarters of the Nation's total. The same four states rank in the top of gas-producing states, but produce only about half of the total. Again, Texas ranks first, but in this case Louisiana is second with California third and Alaska fourth.

The most productive coal Regions are III and VIII with levels of about 213 and 190 hundred million tons respectively per year. Region IV is third with an annual production of about 170 million and Region V is fourth with a production of about 110 million tons. Surface mining out-produces deep mining: about 480 million tons come from surface mines while about 300 million tons are deep mined.

Non-energy Resources

The Minerals Yearbook covers all other mineable resources, but for our purposes here we have limited our interest to copper, iron, and phosphorus. These appear to be the most representative of the characteristic problems associated with mining.

Copper mines are located in 14 states with Arizona leading all in production at 68% of the total. When added with the production of Utah, New Mexico, and Montana, 95% of the Nation's total is represented. Most of the production is from 25 surface mines (84%).

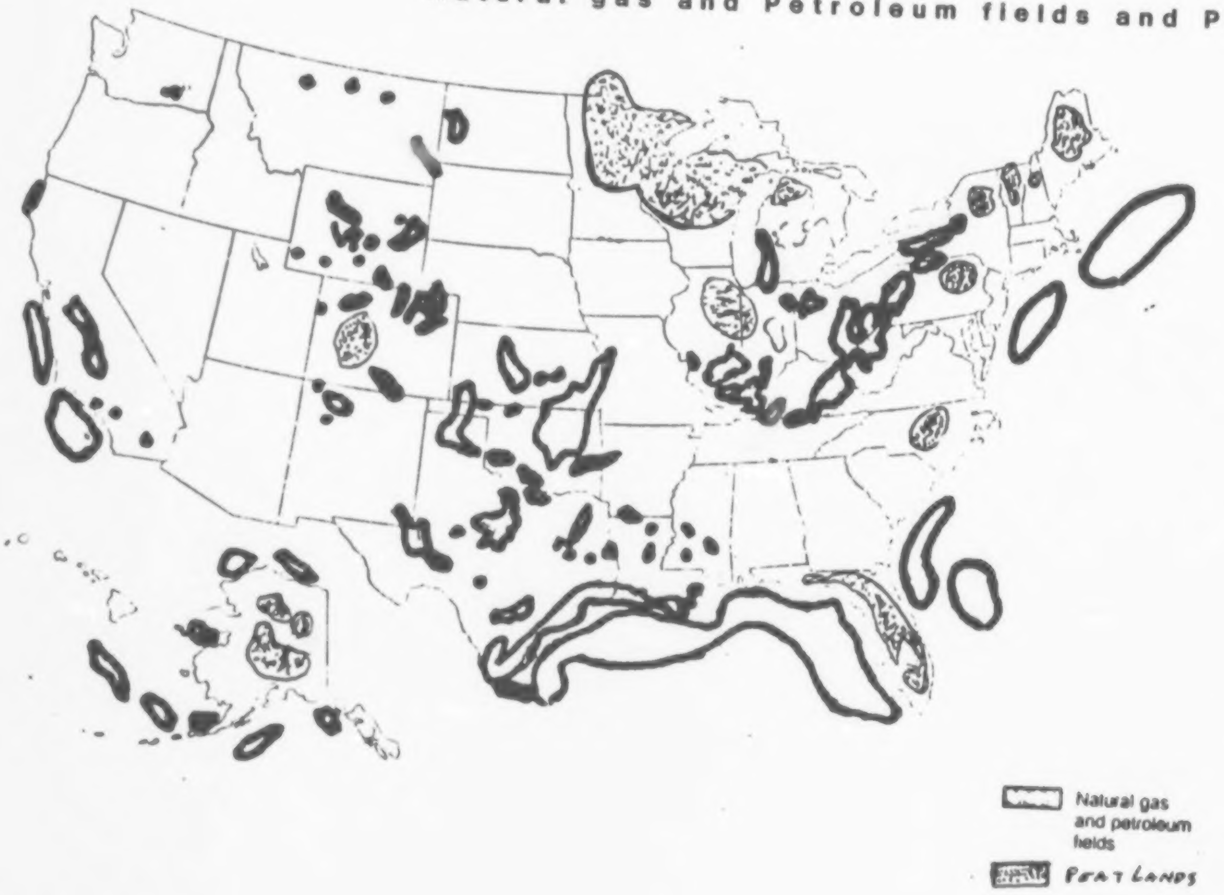
With regard for iron mining, 92% is from mines in the Lake Superior area, located specifically in Minnesota, Michigan, and Wisconsin; thirteen mines are located in Minnesota. Some production also takes place in California, Utah, Wyoming, and Missouri.

Since 18 open pit phosphate mines are located in Florida, this state was exclusively used for this discussion. North Carolina is the only other state with phosphate rock mine of any size. Between them, they produce 87% of the Nation's total. Impacts from mining and processing phosphate are found throughout the environmental media. The ore is taken from surface mines as deep as 50 feet, covering thousands of acres.

About 700,000 tons of peat are mined every year in the Nation, from nearly 100 active mines. The states leading in production are Michigan, Florida, Indiana, and Illinois. Reed-sedge peat accounts for 61% of the total, with humus next at 20%. Hypnum and sphagnum are lowest at 5% and 3% respectively. The highest demands for peat is for potting soil ingredient, soil conditioner, and general nursery uses. Little if any is used as a source of energy, though that was considered several years ago at the height of the energy crisis.

Figure 1

Natural gas and Petroleum fields and Peat lands



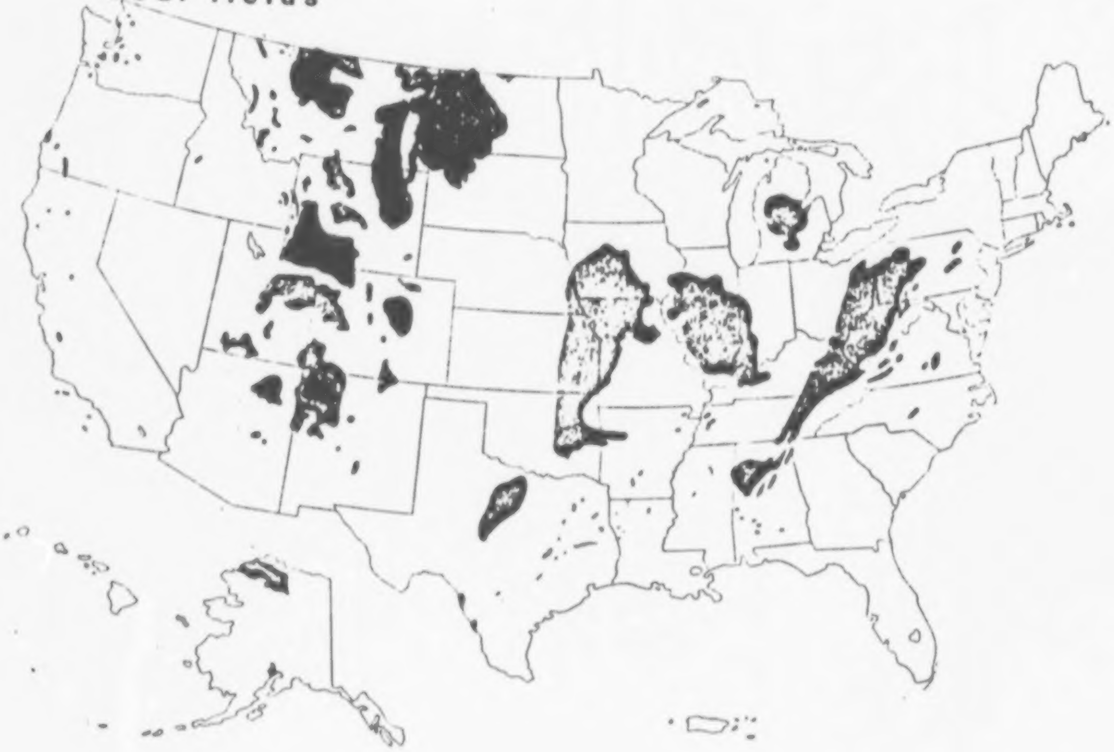
More natural gas and oil are consumed than any other fuel. Oil accounts for roughly half of all energy used and natural gas accounts for a fourth. Both are easy to transport and are generally relatively clean-burning fuels.

Oil and natural gas fields are located primarily in Texas, Oklahoma, and Louisiana and in the outer continental shelf of the Atlantic, Gulf, Pacific, and Alaskan coasts. In 1977, about 10% of oil production was in the outer continental shelf.

In 1977, 2.5 million acres in the outer continental shelf were offered for leasing. Of that, oil companies have leased 1.1 million acres. In a lease sale, the Federal Government sells into private ownership the right to explore, develop, and produce oil and gas. The buyer then explores for oil and gas. If any is found, the buyer pays a royalty based on the amount produced.

Figure. 2

Coal fields



Coal is the Nation's most abundant fossil fuel, making up 95% of fossil fuel reserves. Coal is also one of the most environmentally damaging fuels, emitting fine particulates, hydrocarbons, nitrogen and sulfur oxides, and trace metals when it burns without control.

Anthracite is the hardest and has the highest heat content of the coals. Reserves of bituminous coal are the most abundant. Lignite and subbituminous coals are lowest in sulfur content.

Coal reserves in the East are generally deeper than those in the West, where they can be surface mined. In the West, reclamation of disturbed land is made difficult by the shortage of water.

Impact Evaluation

The work group decided upon a system for evaluating various problems based upon the extent of impact. For example, ozone is considered to be a biosphere problem (worldwide in impact) while a regional problem is considered to be one where the impacts merly cross ecological boundaries and are not world-threatening. The category of resource extraction is almost exclusively regional in nature. Even when limited to a specific site, nearly all activities spill over into neighboring environmental media.

Impacts are discussed in a general way, based upon the four major biomes as determined by the Work Group. However, We think that impacts and stress agents are often broader than the arbitrary categories and this constraint has limited the final picture to some degree. For example, habitat fragmentation is a problem in all categories of resource extraction and, though it is mentioned often in the discussions below, it has broader implications as a stress agent than the some of the other stress agents. In spite of this, we have remained within the boundaries of the committee's rules, by including habitat fragmentation as part of the ecosystem discussions.

Freshwater Ecosystems:

Both deep and surface coal mines have environmental implications that involve impacts to aquatic ecosystems. Surface mining operations have a wider range of impacts than deep mining, but the latter has impacts upon underground water patterns and quality that is difficult to define and control. An example of this is found in the anthracite area of Region III. The beds lie at a steep angle which, when exposed for mining and left unreclaimed, results in conditions that allow water infiltration into the workings. This, in turn, results in continuous production and "flushing out" of acid mine drainage. Potentially, a vast reservoir of low pH water containing high quantities of TDS lies in the ground occupying the abandoned workings. This water forms a "mine pool" that poses a threat to stream and river ecosystems by acid water flowing from natural seeps and manmade boreholes with polluted groundwater as the source.

The geochemistry of Appalachia contains large quantities of pyritic minerals which oxidize into the chemicals that cause acid mine drainage. Over 10,000 miles of streams continue to be degraded in Appalachia (Environmental problems also arise from processing and the by-products of associated operations). Tailings from beneficiation plants contain toxic metals and compounds that are released through the mechanism of acid dissolution. This is a wide spread problem in nearly all coal mining areas east of the Mississippi and is not unknown in other areas where pyritic forms of sulfur are located; metallic pyrites are among the most common minerals worldwide. Put simply, oxidation of pyritic minerals produces sulfuric acid and a precipitate of iron hydroxide. The low pH is deadly to biological systems and the precipitate destroys benthic habitat.

The "area" mines of the midwest expose thousands of acres of coal and in doing so act as a drain for aquifers that are the stabilizing factor in water table maintenance. The disrupted aquifers in the Midwest carry adverse implications for streams, rivers, and lakes through alteration of groundwater as a source.

In all mining and drilling extraction processes, geochemicals are produced that, once exposed to the air, are readily oxidized, and become water soluble pollutants. Regulations currently require treatment for these waters prior to discharge and as a result of this treatment, a sludge is produced that requires disposal. It is a relatively innocuous solid, but almost always poses a disposal problem to the permittee. The regulatory aspects are discussed later in this presentation.

Gas and oil exploration and drilling are a cause of habitat fragmentation. In the Gulf states, canals and channelized streams used for barging equipment and product act as "funnels" for saltwater intrusion and the seaward translocation of freshwater. They cause salinity and flow changes in the hydrologic regime that impact resident populations of fish and fishfood organisms.

Marine and Estuarine:

The marine and estuarine impacts of offshore drilling for gas and oil occur throughout the water column and, in the event of spills, are widespread. However, the greatest impacts of off-shore extraction are felt on the benthic and nektonic populations. Heavy components of oil sink to the bottom, interfering with oxygen exchange, while lighter fractions tend to remain in the surface waters. PAH's (polycyclic aromatic hydrocarbons) in oils impact both surface and benthic organisms. Examples of these compounds are benzo[a]anthracene, phenanthrene, and anthracene. Their impacts are manifested by both inhibited and accelerated growth, interference with photosynthesis, alteration of embryo development, altered osmoregulation, carcinogenesis, mutagenesis, and teratogenesis. In addition, impact is also a result of rock cuttings and drilling muds whereby the ecosystem of both the water column and benthos are impaired. The inputs are continuous and contain several deleterious lubricant and cleansing compounds used in the drilling and extraction processes.

Estuarine and close offshore drilling sites tend to exhibit a broader spectrum of impacts than the marine environment. Near-shore zones in the Gulf are well known for their ecological productivity as well as for their sensitivity to the foreign chemicals produced in drilling operations. In Alaska, causeways that are extended across the land and into the sea interrupt "corridors" that are used by anadromous fish heading for fresh waters to spawn and also fragment the nesting and feeding habitats of shore birds.

Wetlands:

While open water ecosystems are sensitive to drilling for oil and gas and to oil spills, the on-shore exploration and extraction operations are the more damaging, especially in the fresh and saltwater wetland areas of the Gulf states and Alaska. Mining and recreational development of peat bogs is also of major importance resulting in habitat fragmentation.

The major gas and oil areas of both Alaska and the Gulf states are located in the extensive marshes of their coastal zones. These areas are among the most heavily stressed of all the ecosystems. In addition, contaminated water from the excess pumpage often contains hazardous substances and is discharged into the wetlands along with other contaminants used to facilitate the drilling and pumping. In some cases, they are disposed of through underground injection. (See also the chapter on hazardous wastes.)

Hydrologic changes associated with canals and channelized streams to accomodate barges impact the marsh habitat. These changes result in stressed vegetation and subsequent loss of the substrate maintenance capacity of the marsh plants. Erosion follows, allowing shallow and increasingly large salt and brackish lakes to form. They also allow for enhanced seaward flows of land runoff, carrying the nutrients to sea rather than allowing them to be deposited in marshes where they normally end up.

Peat bogs also fall into the category of fragile lands that, once disturbed, cannot be restored using currently available technology. Exploitation for their resources always results in the complete destruction of the habitat. In addition, they are often the preferred habitat of threatened and endangered species as well as selective habitats. For example, peat bogs in Pennsylvania are important to the black bear and peat mining followed by recreational development has had a severe impact upon their populations. Peat bogs are especially attractive to them because they offer both refuge and a good dependable food supply.

Sphagnum bogs are the source of peat and have shown promise in treating some kinds of wastes. While their value and limitations in this regard are still being evaluated, it is known that they are often unaffected by acid mine drainage and even effectively treat it through both their chemical and biological systems.

In general, wetlands are adversely affected by disruption of the hydrologic regime as a result of resource extraction and can also be overwhelmed by excesses of suspended and non-settleable solids. They can also be impacted by the discharges that are in compliance with effluent guidlines. While investigation is still underway, it appears that the acidophilous plants have difficulty surviving discharges of coal mining effluent in the 6 to 9 pH range.

Finally, wetlands are also adversely impacted by the brine effluents of wells tapping resources below the geological salt zone. This is an especially serious problem in the Allegheny Mountains of Pennsylvania.

Terrestrial:

In Alaska, roads and facilities constructed to accomodate the equipment needs of the oil and gas industry disrupt the nesting and feeding ranges of migratory waterfowl. Off-road vehicles used for transporting equipment compress the surface with their tracks and disrupt vegetative continuity. The terrestrial ecosystem is also disrupted by "reserve pits" where drilling wastes are stored. These pits leak their holdings into the surface as well as ground water.

With respect to coal mining, long term problems are caused by abandoned lands of Appalachia where over 600,000 acres of abandoned surface mines are conservatively estimated as still unreclaimed. In the West, lands left either scarred or stacked high with the waste by-products of mining appear to be the problems of greatest concern. Losses of land use are compounded by the toxic potential of the spoil. While the toxicity of the spoil is low, the sheer size of these areas is so large that the ecological impacts are large. A study of such an area in Utah will encompass an area of about 200 square miles. Both the mining operation and its associated accumulation of waste products are further examples of habitat loss and fragmentation. Diversity and productivity are greatly reduced as a result of mining even when the disturbed lands are restored.

Table 2

Status of Land Disturbed by Surface Mining in the United States as of July 1, 1977 by States.[a]

Land Needing Reclamation (acres; dashes indicate none)

State	Reclamation not required by any law: Coal mines	Reclamation not required by any law: Sand and gravel	Reclamation not required by any law: Other mined areas	Reclamation required by law: Coal mines	Reclamation required by law: Sand and gravel	Reclamation required by law: Other mined areas	Land not requiring reclamation	Total land disturbed
Alabama.........	72,292	16,611	19,929	34,807	5,498	6,252	85,673	241,062
*Alaska.........	2,700	4,300	4,000	---	---	---	4,000	15,000
*Arizona........	400	6,400	60,900	---	---	---	121,800	189,500
Arkansas........	5,623	21,483	11,479	2,859	20	1,592	9,449	52,505
California......	10	7,970	80,998	500	17,642	51,316	59,061	217,497
Caribbean Area..	---	2,550	1,000	---	---	---	710	4,260
Colorado........	7,089	8,334	15,861	1,195	11,672	6,513	14,023	64,687
*Connecticut....	---	16,740	787	---	---	---	4,590	22,117
Delaware........	---	2,912	63	---	---	---	1,498	4,473
Florida.........	---	11,162	235,700	---	3,365	20,922	61,266	332,415
Georgia.........	1,680	3,353	24,008	764	4,623	13,772	23,247	71,447
Hawaii..........	---	15	115	---	---	---	---	130
Idaho...........	---	5,100	1,500	---	18,200	3,500	2,500	30,800
Illinois........	118,711	20,330	14,192	40,899	8,582	4,557	88,860	296,131
Indiana.........	25,882	11,875	6,522	74,581	4,176	1,894	64,711	189,641
Iowa............	13,997	10,147	6,421	341	8,457	9,638	10,519	59,520
Kansas..........	41,256	11,150	10,159	815	3,634	3,980	20,117	91,109
Kentucky........	101,637	980	4,712	154,218	2,299	2,780	154,495	421,121
*Louisiana......	---	37,324	2,549	---	---	---	10,467	50,340
Maine...........	---	28,833	2,075	---	2,293	923	6,794	40,918
Maryland........	6,412	7,430	1,181	5,703	9,741	1,734	19,824	52,025
*Massachusetts..	---	32,041	10,330	---	---	---	11,750	54,121
Michigan........	142	39,424	23,422	---	15,662	4,072	27,600	110,322
Minnesota.......	---	30,047	44,801	---	12,444	7,891	66,919	162,102
Mississippi.....	---	45,966	7,821	---	---	---	14,415	68,202
Missouri........	70,688	4,473	28,187	8,772	1,046	6,055	22,051	141,272
Montana.........	1,955	4,655	18,340	4,766	4,492	6,598	12,528	53,334
*Nebraska.......	---	17,969	4,029	---	---	---	11,005	33,003
*Nevada.........	---	1,221	2,555	---	---	---	1,953	5,729
*New Hampshire..	---	12,725	417	---	---	---	547	13,689
*New Jersey.....	---	24,610	5,570	---	---	---	8,263	38,443
New Mexico......	22	11,860	1,806	3,709	1,057	26,072	2,207	46,733
New York........	---	30,917	19,251	---	15,979	5,037	18,477	89,661
North Carolina..	---	11,908	4,792	---	7,096	3,909	7,000	34,705
North Dakota....	1,050	2,010	200	6,725	---	---	38,595	48,580
Ohio............	196,709	22,621	18,923	77,050	16,659	8,427	190,578	530,967
Oklahoma........	36,118	6,659	14,105	6,298	2,766	4,110	16,255	86,311
Oregon..........	---	3,521	17,568	3	6,814	1,538	7,387	36,831
Pennsylvania....	240,000	11,000	20,500	60,000	15,000	25,000	250,000	621,500
*Rhode Island...	---	2,592	---	---	---	---	3,470	6,062
South Carolina..	---	9,065	2,128	---	4,395	3,194	9,815	28,597
South Dakota...	890	10,153	5,259	---	6,826	695	7,149	30,972
Tennessee.......	29,583	4,950	2,305	3,127	810	1,135	104,596	146,506
Texas...........	3,310	152,457	37,104	3,725	6,289	4,989	48,456	256,330
Utah............	635	3,999	4,414	133	4,637	10,216	7,521	31,555
Vermont.........	---	3,877	2,078	---	377	60	1,536	7,928
Virginia........	23,724	3,788	1,251	8,222	3,929	2,003	70,060	112,977
Washington......	48	9,701	8,174	1,190	11,822	1,073	10,245	42,253
West Virginia...	84,868	4,554	995	7,658	---	---	137,105	235,180
Wisconsin.......	---	41,607	7,555	---	11,884	2,865	21,605	85,516
Wyoming.........	9,657	3,673	12,376	62,028	7,665	12,787	5,511	113,697
TOTAL	1,097,088	799,042	830,407	570,088	257,851	267,097	1,898,203	5,719,776

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a/ From USDA, 1980. Soil and Water Resource Conservation Act: Appraisal 80. Review Draft. Part I.

* No State law when survey completed; therefore, no reclamation by law.

Severity Evaluation

The formula below has been used to evaluate the severity of "impact/risk" associated with resource extraction and to arrive at a relative ranking of them:

$$Ge\ (I + F + D) = R$$

Ge is geographical extent: miles, acres, volumes, etc.
I is intensity: severity of impacts
F is frequency: coefficient of recurrence
D is duration: recovery time
R is Impact/Risk: factor applicable to effects

Since the impact/risk is felt by the biome and that biome can be viewed as a geographical unit or area, all other factors (i.e., Intensity, "I", Frequency, "F", and Duration, "D") affect it. Thus, mathematical manipulation produces a factor that is used to compare the impact/risk of the stress agents upon the biomes.

The variables were estimated for each stress agent's affect upon the biomes, based upon the literature citations and the authors' judgements. The relative rankings of the 14 stress agents in each of the four ecosystems are shown in Table 4 and graphically represented in Figure 1. The graphs are intended to be relative indices of the severity of stress agents within each biome. No pretense at scientific precision is intended; rather, the graphical representation is meant to be used as a qualitative ranking in understanding the relative importance of each stress agent in each of the four ecosystems.

Furthermore, the impacts are evaluated for severity where they occur and not judged for any comparative values with any other pollutants from the universe of water pollution problems. For example, acid mine drainage impacts stand alone for miles of streams impacted and no attempt was made to compare its severity with that of pollution from urban runoff, solid wastes or any other covered by other work group members.

Figure 3: Summary of impacts of stress agents upon ecosystems.

The fourteen categories on the abscissa correspond to the stress agents in table four and are listed here for reference:

1 Acid Mine Drainage

2 Toxic Inorganics

3 Nutrients
4 Turbidity

Oils
  5 Machinery
  6 Spills

Solids
  7 Mine Spoil
  8 Beneficiation & Refining Wastes
  9 Use-Byproducts

Habitat Alteration
  10 Canals
  11 Causeways
  12 Dredging/Channelization

Groundwater
  13 Disruption
  14 Contamination

Table 4

Summary of Imacts on Ecosystems

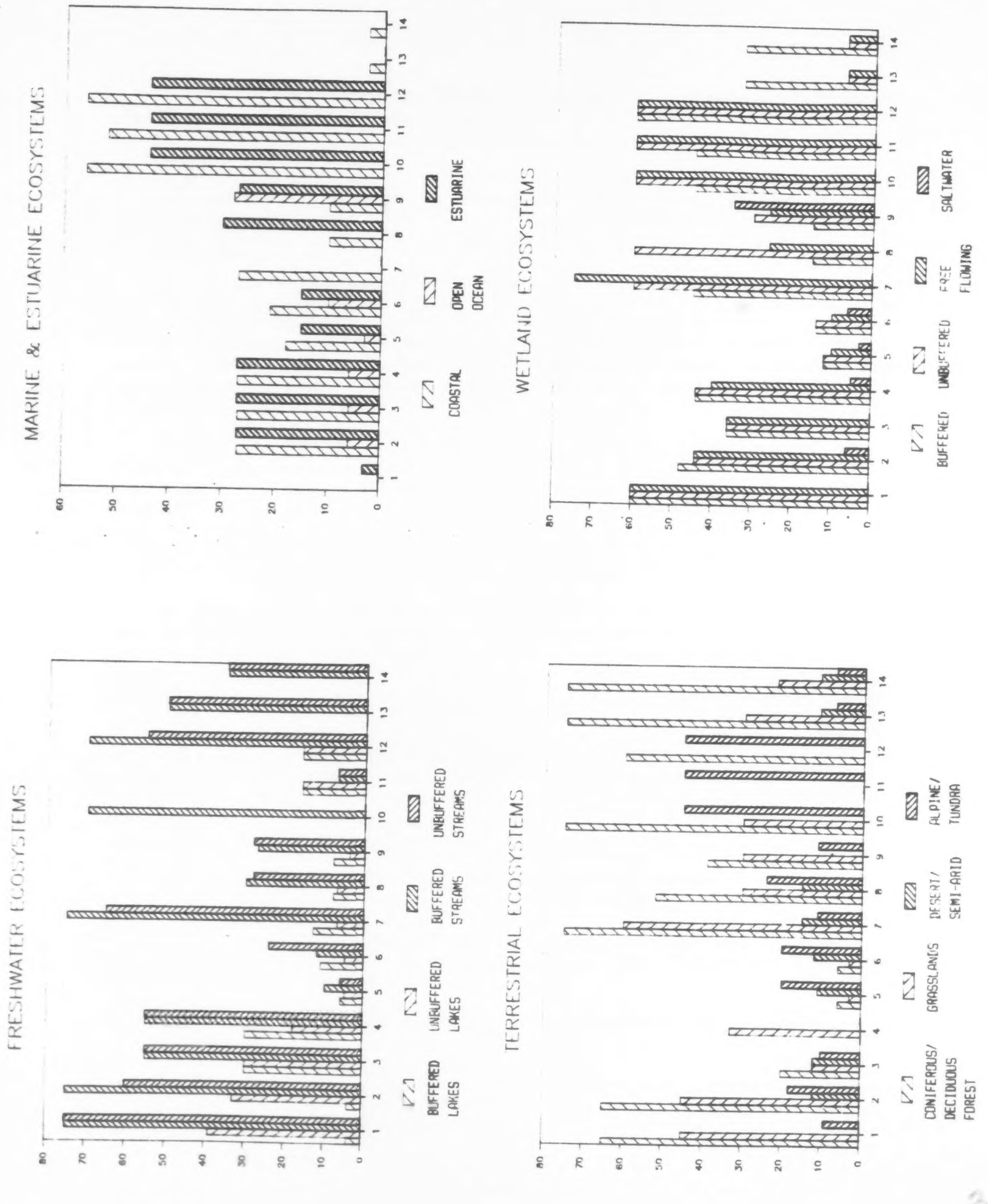
Stress Agents	Freshwaster				Marine/Estuarine			Terrestrial			
	BUFFERED LAKES	UNBUFFERED LAKES	BUFFERED STREAMS	UNBUFFERED STREAMS	COASTAL	OPEN OCEAN	ESTUARINE	CONIFEROUS/ DECIDUOUS FOREST	GRASSLANDS	DESERT/ SEMI-ARID	ALPINE/ TUNDRA
Acid Mine Drainage	4	39	75	75	0	0	3	65	45	0	9
Toxic Inorganics (heavy metals)	4	33	75	60	27	6	27	65	45	12	18
Nutrients	30	30	55	55	27	6	27	20	12	12	10
Turbidity	30	18	55	55	27	6	27	0	33	0	0
Oils											
Machinery	6	5	10	6	18	3	15	6	3	11	20
Spills	11	5	12	24	21	10	15	6	3	12	20
Solids											
Mine Spoil	13	7	75	65	27	0	0	75	60	15	11
Beneficiation & Refining Wastes	8	7	30	28	10	0	30	52	30	15	24
Use-Byproducts	8	4	27	28	10	28	27	39	30	0	11
Habitat Alteration											
Canals	0	0	70	0	56	0	44	75	30	0	45
Causeways	16	16	7	7	52	0	44	0	0	0	45
Dredging/ Channelization	16	16	70	55	56	0	44	60	0	0	45
Groundwater											
Disruption	0	0	50	50	3	0	0	75	30	11	7
Contamination	0	0	35	35	3	0	0	75	22	11	7
AVERAGE	11	14	50	42	26	5	23	47	36	8	21
RANK											

Table 4 Con't.

Wetlands

Stress Agents	BUFFERED	UNBUFFERED	FREE FLOWING	SALTWATER	AVERAGE
Acid Mine Drainage	60	60	60	0	33
Toxic Inorganics (heavy metals)	48	44	44	6	34
Nutrients	36	36	36	0	26
Turbidity	44	44	40	5	26
Oils					
Machinery	12	12	10	3	9
Spills	14	14	10	6	12
Solids					
Mine Spoil	45	60	75	0	35
Beneficiation & Refining Wastes	15	60	26	0	22
Use-Byproducts	15	30	26	35	21
Habitat Alteration					
Canals	45	60	60	0	32
Causeways	45	60	60	0	23
Dredging/ Channelization	60	60	60	0	36
Groundwater					
Disruption	33	7	7	0	18
Contamination	33	7	7	0	16
AVERAGE	39	43	40	4	27

Figure 4



MARINE & ESTUARINE ECOSYSTEMS
COASTAL
OPEN OCEAN
ESTUARINE
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
11
12
13
14
WETLAND ECOSYSTEMS
BUFFERED
UNBUFFERED
FREE FLOWING
SALTWATER
0
10
20
30
40
50
60
70
80
FRESHWATER ECOSYSTEMS
BUFFERED LAKES
UNBUFFERED LAKES
BUFFERED STREAMS
UNBUFFERED STREAMS
TERRESTRIAL ECOSYSTEMS
CONIFEROUS/ DECIDUOUS FOREST
GRASSLANDS
DESERT/ SEMI-ARID
ALPINE/ TUNDRA

In reading the graphs, the reader should beware that some assumptions and arbitrary groupings were made in developing the categories. For example, the category of mine spoil can also be viewed as acid spoil and includes:

- acid mine drainage
- total dissolved solids
- turbidity
- nutrients
- drastically changed runoff quantity & patterns
- unrelaimed culm or refuse piles
- lands disturbed for support facilities
- unsuccessfulr eclamation efforts

All of these adversely impact terrestrial ecosystems through depressed pH of both surface and pore water of the soil, release of metals and nutrients, and deposition of suspended solids carried by the changed runoff patterns. For this reason, mine spoil as a stress agent invades the territory of other stress agents. However, we do not feel this should lead the reader to conclude lesser impacts from the other categories because they still stand on their own as relatively serious problems.

In the category of habitat alteration, canals are differentiated from channelized streams according to the traditional definitions. Canals are waterways that are created where none existed previously. Channelization refers to streams that have been dredged to accomodate barge traffic that could not otherwise negotiate the waterway. Both impact freshwater wetlands as well as the marine/etuarine environments by virtue of creating a free exchange and enhanced mixing of fresh and salt waters, equally impacting the ecological regime of each.

On first blush, some categories may appear to be skewed too high or too low; however, this is due to the definitions used in setting up both the stress agents and the environmental categories, making for some very broad categories and wide ranging impacts. For example, the impact of habitat alteration on buffered streams is high, according to our scheme, because a buffered stream includes streams with a calcium carbonate equivalency of 20 mg/l as well as some streams that may be protected from minimal pH changes by such naturally occuring organcic compounds as as tannic acid. This scheme gives a spectrum of streams that includes the vast proproportion of all streams. As a result, canals show a great deal of impacts to buffered, but little to unbuffered streams. This phenomenon is also partially attributable to the fact that, to our knowledge, unbuffered streams are located in areas where canals are not feasible.

The reader will see that this scheme results in a means for evaluating stress agents for their varied impacts among the four biomes. For example, number one, acid mine drainage, shows moderate to high impacts in all by marine/estuarine. Further selection can be made by noting that buffered and unbuffered streams are more severely impacted than buffered lakes. The table below lists the four biomes and their high impact stress agents.

Freshwater: acid mine drainage, toxic inorganics, mine spoil, canals, and dredging/channelization.

Marine/estuarine: habitat alteration (canals, causeways & dredging/channelization)

Terrestrial: acid mine drainage, mine spoil, toxic inorganics, canals, groundwater (disruption and contamination).

Wetlands: acid mine drainage, mine spoil, beneficiation wastes, canals, causeways, and dredging/channelization.

Regulations

Table 3, below, describes 6 Federal Acts that cover all parts of the four ecosystems of interest. The responsibilities are fragmented among at least four agencies, with divided regulatory authorities among many of them.

Table 3: Legislation:

ECOSYSTEMS

ACT	Freshwater	Marine/ Estuarine	Terrestrial	Wetlands	AGENCY
	Lakes & Streams	Open Ocean, Coastal, Estuarine	Forests, Grasslands Desert, Alpine/ tundra	Fresh, Free-flowing Saltwater	
Clean Water Act:					
402 (NPDES)	x	x		x	EPA/States
404 PERMITS	x	x	x	x	COE/EPA
Clean Air Act					
New Source Rev.			x		EPA/States
New Source Perf.			x		" "
PSD			x		" "
RCRA	x	x	x	x	EPA
SMCRA	x		x	x	OSM (USDI)
Rivers & Harbors Dredge & Fill	x*	x		x*	COE/EPA
Marine Sanct. & Protection					
Permits (Dredge & Fill)		x			COE/EPA
Sanctuaries		x			NMFS (NOAA)

* Covering waters declared to be navigable

Extraction wastes and beneficiation by-product disposal is also a major concern. In the past, unwanted soil and rock have been left haphazardly stacked at any convenient location out of the way. The Surface Mining Control and Reclamation Act of '77 covers coal mining only, leaving controls on other mining (except uranium) solely to state regulations.

Liquid wastes are usually dumped into waterways or evaporation ponds. Underground injection into abandoned underground workings has also been widely used. the subject has come to EPA's attention in the past few years and will undoubtedly undergo further scrutiny, with this method of disposal of acid mine drainage treatment plant waste receiving attention. All resource extraction methods should be looked at for such geochemicals and, where necessary, regulatory programs be developed.

Recommendations:

While it is apparent that a great deal of work on characterizing impacts to the ecosystems for many stress agents, sufficient information is available to make some strides towards tightened controls.

- In the area of coal mining, EPA can initiate close cooperation with OSM to include water quality benefits, where appropriate, to sites being reclaimed using Abandoned Lands Funds. SMCRA has specified that funds are to be allocated initially for correcting conditions where hazards to human health and safety are imminent. In many cases, an incremental amount could secure considerably greater benefits in water quality.

- EPA should consider cooperation with OSM on the issue of permits consolidation. Currently, individual permits are issues for SMCRA and NPDES . Considerable overlap exists between the two that could be eliminated through consolidation. In addition, a separate permit system covers the wetlands aspects. While these concerns are often covered through the NPDES and the SMCRA permit systems, mining operators often overlook the requirements of CWA Sect. 404.

- The control of acid mine drainage still ranks as one of the major unresolved problems. The status is that premine analyses commonly used is not wholly reliable and the more reliable methods is both time consuming and costly. In addition, postmining reclamation also has a sketchy record, resulting in many closed mines contributing acid mine drainage through toe slope seeps. Abandoned mines that remain unreclaimed are far and away the greatest sources of acid mine drainage. EPA should reawaken interest in these issues and resurrect past activities that were aimed at identifying and testing analytical and treatment techniques.

- Habitat fragmentation from oil and gas exploration and drilling should be given closer attention by EPA than it currently receives. Both funding and personnel resources are needed along with increased coordination with the Corps of Engineers.

- Many mining operations drastically alter or even destroy habitats of high value. An example is the phosphorus mines of Florida. EPA should recognize that a substantial effort is needed to develop mitigation and reclamation techniques.

Sources and Selected References

Alexander, M.H. 1983. Oil, Fish and Wildlife, and Wetlands (A Review) North eastern Environmental Science. 2:1:13-24.

Ambrose, Robert B., Jr. & D. Disney. 1986. The Computerized Ecological Risk System (CERAS) -- Functional Objectives and Prototype System. US EPA OR&D Prepared for Exposure Evaluation Division; Office of Toxic Substances.

Biddinger, G. R. & S.P. Glass. 1984. The Importance of Trophic Transfer in Bioaccumulation of Chemical Contaminants in Aquatic Ecosystem. Springer-Verlag.

Bosch, D.F. 1982. Proceedings of the Conference on Coastal Erosion and Wetlands Modification in Louisiana: Causes, Consequences, and Options. Us F&WS, Biological Services. FWS/DBS-83/26.

Boulding, R. 1984. The Lost Harvest: A Study of the Surface Mining Act's Failure to Reclaim Prime Farmland in the Midwest. in: The Illinois South Project.

Buc & Assoc. 1986. Locations of Mines and Factors Affecting Exposures. FR 51 No. 128:24501.

Charles River Assoc. 1986. Federal Non-EPA Regulations Addressing Mining Waste Practices. FR/51 No. 128:24501.

DeLaune, R.D. et al. 1978. Sedimentation Rates Determined by 137Cs Dating in a Rapidly Accreting Salt Marsh. Nature 275: 532-533.

Frontier Technical Assoc. 1986. Groundwater Monitoring Data on Ore Mining and Milling Solid Waste Disposal.

Gagliano, S.M. 1981. Special Report on Marsh Deterioration and Land Loss in the Deltic Plain of Coastal Louisiana.

Merrill, T.J. & K.V. Koski. 1979. Habitat Values of Coastal Wetlands For Pacific Coast Salmonids. in: P.E. Gleeson, et. al. Wetland Functions and Values: the State of Our Understanding. Amer. Water Resources Assoc. pp 256-266.

Neill, C. & S. Leibowitz. 1983. Modified Habitat Data for the Mississippi Deltaic Plain and Chenier Plain Regions. Louisiana State Univ., Ctr. for Wetland Resources, Baton Rouge.

Overton, J.A. 1984. Is America Rushing into Wilderness? American Mining Congress Journal. 70:20.

Pursell, P. L. 1983. Problems with Determining Trends in Land Use Changes Following Coal Mining in Illinois. in: Proceedings, Third Annual Conference, Better Reclamation with Trees. Purdue Univ.

Richardson R.V. & G.F. Nielsen. 1984. Keystone Coal Manual. McGraw-Hill Mining Publications.

Reisch, D.J. 1984. Fate and Effects of Pollutants. Jnl. WPCF. 56:6:758ff

Strauch, R. E. 1980. Risk Assessment as a Subjective Process.

_____ . 1974. A Critical Assessment of Quantitative Methodology as a Policy Analysis Tool. The Rand Corp., P-5282.

Stream Pollution By Coal Mine Drainage In Appalachia. 1969. USDI/FWPCA. (out of Print)

US COE. 1984. Notice of Study Findings: Land Loss and Marsh Creation in the Lousiana Coastal Area, Lousiana. US COE/New Orleans Dist.

US Dept. Of Energy. 1986. Natural Gas Monthly. Publ. No. DOE/EIA 0130

US Dept. Of Energy. 1985. Petroleum Supply Annual for 1985. Publ. No. DOE/EIA 0340.

US EPA. 1978. Central Florida Phosphate Industry Areawide Impact Assessment. Vol. VIII. Alternative Effects Assessment p 147ff PB-296590/3

US EPA. 1985. Code of Federal Regulations: 40:257.1ff.

US EPA. 1986. Regulatory Determination for Wastes from the Extraction and Beneficiation of Ores and Minerals. FR/51 No. 128:24496 (40 CFR Part 261).

USDI/BOM. 1981. Minerals Yearbook: Centennial Edition. Vol.I: Metals and Minerals.

USDI. 1984. The Ecology of Delta Marshes of Coastal Lousiana: A Community Profile. USDI/FWS & US DOD/COE. FWS/OBS - 84/09

USDI. 1967. Surface Mining and Our Environment: A Special Report to the Nation.

Varnasi, U. et al. 1985. Bioavailability and Biotransformation of Aromatic Hydrocarbons in Benthic Organisms... Environmental Science and Technology.

19:9:836-841.

Wali, M.K. 1977. Energy and Coal Resources Development. Pergamon Press.

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Environmental Problem: Accidental Releases -- Toxics (#21)

Accidental releases of toxic chemicals occur during the transport of chemicals or at production facilities. Transport involves truck transport via highways, barge transport on inland waterways, pipeline transport, rail transport, and tanker transport offshore and in large inland water bodies. Releases of toxic chemicals occur in all media and involve a wide range of chemicals.

Available data (which is acknowledged to understate releases) indicate that there are about 2,000 accidental releases of CERCLA listed chemicals per year, resulting in an average of about 40 million pounds of releases per year. (The number of releases is relatively similar from year to year, but the quantity of releases varies considerably.) About 12 percent of releases are to water. Of this, about 3.5 percent are to sewers (and may have subsequent effects if POTWs cannot adequately treat the released material), about 1.5 percent are to the oceans, and about 8 percent are to inland waterways.

Most accidental releases involve relatively small quantities of material. But it is the infrequent, large quantity, releases that dominate in terms of total material released -- only 2.4 percent of the number of releases account for over 90 percent of the quantity of material released. The types of chemicals released in greatest quantities and highest frequencies are acids, bases, and non-persistent organics (PCB releases are mostly to land).

Accidental releases of toxic substances are unlikely to substantially affect terrestrial ecosystems, but they may create significant localized effects of short duration to freshwater ecosystems. Releases to marine, estuarine, and wetland ecosystems are infrequent, but could result in significant localized effects. There always exists the potential that low probability events involving releases of large volumes of highly toxic and persistent compounds coud result in significant and persistent local and regional effects to marine environments.

Environmental Problem: 21, Accidental Releases -- Toxics

I. Description of Sources

Accidental releases of toxic chemicals occur during the transport of chemicals or at production facilities. Transport involves truck transport via highways, barge transport on inland waterways, pipeline transport, rail transport, and tanker transport offshore and in large inland water bodies. Releases of toxic chemicals occur in all media and involve a wide range of chemicals. Depending on the specific case, the effects of an accidental release can vary from being minor, to causing significant short term, but no long term, effects, to causing persistant and substantial damage. Substantial ecological effects are more likely for spills into water because of the potential for the spread of the chemicals and the difficulty of containing and removing or treating the released materials.

Accidental releases are infrequent, probabilistic events, which makes it difficult to forsee whether accidents in the future will have severe environmental consequences, such as the recent disaster at Basel, Switzerland. The approach followed here is to summarize reported information on the frequency, general locations, and volume of releases and on the types of chemicals most frequently released to develop a general indication of the likely severity of ecological effects from releases of toxic chemicals.

II. Detailed Description of Sources, Releases, and Exposures

The data[1] in the table below indicate that there are about 2,000 accidental releases of CERCLA listed chemicals per year, resulting in an average of about 40 million pounds of releases per year (the number of releases is relatively similar from year to year, but the quantity of releases varies considerably).

	NRC Notifications of Releases of CERCLA Chemicals	
Year	Number	Quantity (million lbs)
1982	1,664	10.7
1983	2,014	93.6
1984	1,991	11.1
1985E	2,523	-
Avg.	2,048	38.5

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[1] The data relied on are acknowledged to underreport the number of releases, possibly by a factor of 2 or more, and the volume of releases. Most releases are reported to some governmental authority, either at the local, state, regional, or national level. Cleanup responses then usually are initiated if needed. However, if releases are reported to agencies other than the National Response Center (NPC), it is likely that the releases are not included in the NRC data base referenced by this paper.

Most of these releases are from fixed facilities and are restricted to land, as shown below. Of the 12 percent of releases to water, about 3.5 percent are to sewers (and may have subsequent effects if POTWs cannot adequately treat the released material), about 1.5 percent are to the oceans, and about 8 percent are to inland waterways.

Mode	Percent Distribution of Number of Releases 1982-85 by Mode
Higway	7.9%
Marine	1.2
Pipeline	1.6
Rail	13.3
Offshore	0.2
Fixed Facility and other	75.9

Medium	Percent Distribution of Number of Releases 1982-85 by Mode
Air	16.0%
Land	53.7
Water	12.0
Unknown	18.3

Accidental releases of toxic chemicals are probabilistic events. Accidental releases typically involve relatively small quantities of material, but it is the infrequent, large quantity releases that dominate in terms of total material released. This is shown in the table below, where only 2.4 percent of the number of releases account for over 90 percent of the quantity of material released.

Pounds Released	Distribution of Number and Volume of Releases, by Size of Release, 1982-84	
	Number	Quantity
<10	9.9%	-
10-100	42.3	0.1%
100-1,000	19.6	0.3
1,000-10,000	16.0	2.4
10,000-100,000	9.7	12.8
100,000-1,000,000	2.1	22.5
>1,000,000	0.3	67.8

The types of toxic chemicals rleased in largest quantities generally are common production chemicals. In 1983, however, there were a number of large volume spills that tend to skew the numbers (this is inherent in probabilistic type releases). Provided below is information on the percentage volume releases for chemicals released in greatest quantities and the frequency of releases for the most frequently released chemicals.

	Percent Distribution of Volume of Releases and of Frequency of Release		
	Volume of Top Ten		Frequency of Top Ten, 1982 to 1985
Chemical	1982 & 1984	1982 to 1984	
Sulfuric Acid	20.6%	30.1%	8.1%
Hydrochloric Acid	10.3	3.0	4.0
Sodium Hydroxide [a]	9.0	3.7	2.3
Caustic Soda Solutin [a]	5.1	3.3	2.1
Methyl Alchohol	4.2	1.1	
Nitric Acid	3.6		
Phosphoric Acid	3.2		1.5
Benzene	3.2	17.7	
Ferric Chloride	3.1		
PCBs	2.7	16.7	35.6
Toluene	2.4		
Potassium Cyanide		3.9	
Sodium Cyanide		2.3	
Radioactive Material		1.7[b]	
Anhydrous Ammonia			6.0
Chlorine			6.2
Methyl Chloride			2.6
Vinyl Chloride			1.6
TOTAL	64.4%	81.2%	70.0%

[a] Substances chemically identical; caustic soda is in solution.
[b] Mostly uranium mill tailings.

PCBs are reported spilled with the greatest freequency. About 90 percent of these involve power companies and occur primarily as a result of equipment failure and of maintenance activities. Most PCB releases, thus, would be confined to land. They are expected to decline as the PCB phase out continues. Releases of anhydrous ammonia, chlorine, methyl chloride and vinyl chloride are reported frequently but do not account for a large volume of releases. This is because the reportable quantities for these chemicals are set very low -- 100, 10, 1 and 1 pounds, respectively.[2]

Response actions are taken to address most spills, but the extent to which releases of toxics are contained, removed from the environment, or neutralized is unclear. Releases to the air cannot be addressed except through removal of the source. However, such releases would likely have only short term effects (if any) on ecological systems. Releases to land generally can be contained and effectively remedied. Given that most releases are from fixed facilities, important and sensitive land-based ecosystems probably are not very often affected. Releases to marine environments are the most problematic. The ability to remedy the spill will depend on a host of factors specific to the incident. The consequent effects of the residual release on the aquatic environment will depend on the characteristics of the chemical (persistance, bioaccumulative properties, and toxicity). We do not have information to characterize the short and long term effects of releases already experienced. However, given the types of chemicals released in greatest quantities and highest frequencies -- mostly acids, bases, and non-persistant organics (PCB releases are mostly to land) -- it would appear that most ecological impacts would be localized and of short duration. This observation, of course, does not rule out the potential for a natural disaster at a regional level from an accidental releases of large volumes of highly toxic and persistant chemicals.

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[2]/ If a release exceeds the "reportable quantity," the responsible party is required to notify the NRC and report the release.

III. Evaluation of the Problem

The available information suggests that:

1) terrestrial ecosystems are unlikely to be substantially affected;
2) freshwater ecosystems are likely to have significant localized effects from releases, but they are likely to be of short duration;
3) marine and estuarine systems are infrequently affected by releases;
4) wetland ecosystems could have significant localized effects (probably of short duration) but releases to such systems occur infrequently; and
5) there always exists the potential for highly significant and persistant local and regional effects to marine environments from low probability events involving releases of large volumes of highly toxic and persistent compounds.

Sources of information:

U.S. Department of Transportation, Transportation System Center, Addendum, Patterns and Trends for National Response Center Hazardous Releases, July 1985.

U.S. Department of Transportation, Transportation System Center, Patterns and Trends, National Response Center Data, 1982-1985 Update, with Quantities, Injuries, and Fatalities, March 1986.

Environmental Problem: Accidental Releases -- Oil (#22)

Accidental releases of oil occur during the transport of oil in vessels, tank trucks, and pipelines; from marine- and land-based transfer facilities; and from refinery, bulk storage, and on- and offshore production facilities. Releases of oil range from crude petroleum to gasoline and other distillates. We focused only on releases to water, as it is likely that ecological effects would be of larger scale and more severe for aquatic rather than for terrestrial ecosystems.

On average, there are over 9,000 oil spills per year resulting in releases of about 11 million gallons of oil. Most reported spills are fairly small -- over 90 percent of spills for which the release volumes are reported are less than 1,000 gallons. On the other hand, the relatively small number of spills greater than 10,000 gallons, about 1.3 percent of reported spills, account for over 80 percent of the volume of spills.

Although oil spills to water are frequent events, generally the amounts spilled or left unrecovered after cleanup activities are small enough so that natural systems are not significantly threatened. The very infrequent large size spill in confined waters can cause significant short term localized damage. However, even in such cases the combination of cleansing processes of natural systems, weathering of oil, and cleanup efforts have resulted in ecosystems recovering relatively quickly.

Environmental Problem: 22, Accidental Releases -- Oil

I. Description of Sources

Accidental releases of oil occur during the transport of oil in vessels, tanker trucks, and pipelines; from marine- and land-based transfer facilities; and from refinery, bulk storage, and on-and offshore production facilities. Releases of oil range from crude petrolium to gasoline and other distillates. Releases can occur to all media, but the focus here is on releases to water, as data are available to characterize releases to that medium and it is likely that ecological effects would be of larger scale and more severe for aquatic rather than terrestrial ecosystems.

II. Detailed Description of Sources, Releases, and Exposures

The data in the table below indicate that, on average, there are over 9,000 spills per year resulting in releases of about 11 million gallons of oil.[1]

Number and Quantity of Oil Spills
1979 - 1983

Year	Number	Quantity (000 gal.)
1979	10,990	10,500
1980	9,194	10,171
1981	8,820	17,800
1982	8,612	9,188
1983	9,208	8,270
Avg.	9,365	11,186

Most reported spills are fairly small -- over 90 percent of spills for which the releases volumes are reported are less than 1,000 gallons. On the other hand, the relatively small number of spills greater than 10,000 gallons, about 1.3 percent of reported spills, account for over 80 percent of the volume of spills. This is shown in the table below. The data indicate that it is the infrequent, large release event that dominates releases to the environment.

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[1] Some small spills may not be reported. Many spills reported are from unknown sources, are of unknown quantity, or are sheens that have been observed.

	Distribution of the Number and Quantity of Spills, by Spill Size 1982 and 1983[a]	
Spill Size	Number	Quantity
<10	39.5%	0.1%
10-99	36.5	0.9
100-999	16.8	3.6
1,000-10,000	5.8	13.3
10,000-100,000	1.1	21.3
100,000-1,000,000	0.2	35.9
>1,000,000	<0.1	25.0

[a] About 28 percnt of reported spills either are of unknown quantity or are sheens. Such spills are not included in the above calculations.

The distribution of oil releases by type of product is shown in the table below. Crude oil accounts for over 40 percent of releases and diesel and fuel oil together account for about 30 percent. Average spill sizes are similar for most products -- about 1,000 gallons.

	Distribution of Oil Spills by Type of Product, 1982 and 1983	
Product	Number	Quantity
Crude Oil	24.2%	41.6%
Gasoline	6.0	7.5
Other distillate	2.4	3.6
Solvents	0.6	0.4
Diesel oil	22.6	17.2
Fuel oil	5.2	11.3
Asphalt/Tar/Pitch	1.0	0.7
Animal/Veg. Oil	0.3	1.1
Waste Oil	8.0	6.6
Other oil	29.4	9.9

Over 70 percent of the quantity of oil spills occurs in inland areas as opposed to coastal areas as shown below. The average spill size in inland areas is about double that for coastal areas.

	Distribution of Oil Spills by General Areas, 1982 and 1983	
General Area	Number	Quantity
Inland	41.3%	73.1%
Atlantic	20.3	4.8
Pacific	12.7	8.2
Gulf	24.4	12.6
Great Lakes	0.4	0.1
Other	0.7	1.2

Within inland areas, most spills affect rivers, beaches, and non-navigable waterbodies, as shown below.

Location	Distribution of Spills in Inland Areas, by Location, 1982 and 1983	
	Number	Quantity
Open internal waters	14.1%	10.8%
River chanels	46.3	45.1
Ports & harbors	10.5	2.9
Beaches & non-navig.	29.0	41.2

Spills in coastal areas are mainly in ports and harbors and in the rivers connecting terminal facilities to harbors. The distribution of spills by location for the combined coastal areas is shown below.

Location	Distribution of Spills for the Atlantic, Pacific, and Gulf Areas by Location, 1982 and 1983	
	Number	Quantity
River channels	25.0%	37.7%
Ports & harbors	30.4	35.0
Beaches & non-navig.	3.4	4.2
Shore - 3 MI	14.1	16.2
3-12-MI	9.8	4.0
High Seas	17.2	3.0

Most of the spills in river channels are on the east coast and most of the spills in the 3-12Mi and high seas locations are in the Gulf coast area.

In summary, the information on releases indicates that: (1) there are a substantial number of spills each year, but the bulk of these are under 1,000 gallons; (2) a relatively small number of large spills dominates the volume of releases; (3) most releases are of crude oil and diesel and fuel oils, (4) most releases are in inland areas; and (5) rivers, beaches, and non-navigable waterways mostly are affected by spills in inland areas.

Assessing the likely environmental consequences of future oils spills is problematic because they are probalistic events. The impact in an ecosystem would depend on many factors, such as the size of spill, the product, location of the spill, and the ability to contain, collect or disperse the spill. Spills would have the most severe impacts if: [2]

- The spill is in a confined, shallow water body and the volume of the spill is large relative to the body of water;

2/ See McAuliffe, "Fate and Effects of an Oil Spill from Canadian West Coast Offshore Exploration," in Offshore Hydrocarbon Exploration, West Coast Offshore Exploration Environmental Assessment Panel, April 1986.

- the oil is a light, refined oil, such as home heating or diesel oil; and
- there is a high load of fine sediment in the water column.

Spills of this type are rare, but can significantly reduce populations of benthic (bottom feeding) communities for years. However, even for these kinds of spills (Torrey Canyon, Metula, and Amoco Cadiz) the shoreline plants and animals have recovered over time. Spills of oil in lesser amounts, and in unconfined waters have less severe short term impacts. Weathering of oil and cleansing properties of natural systems in such circumstance generally result in fast recoveries of those systems.

A series of case studies of spills is presented in the 1985 Oil Spill Conference Report. They involve a near shore spill, a spill on arctic tundra, a spill to an estuary, and spills to a freshwater river, wetland, and creek. Short term damage was limited because of the nature of the systems and cleanup responses. All systems recovered from the spills within a year or two.

III. Evaluation of the Problem

The information indicates that oil spills to water are frequent events. But, generally, they are in amounts small enough, in combination with cleanup activities, to not significantly threaten natural systems. The very infrequent event of a large size spill in confined waters can cause significant short term localized damage. However, even in such cases the combination of natural cleansing processes and cleanup efforts have resulted in ecosystems recovering relatively quickly.

Sources of Information:

U.S. Department of Transportation, Polluting Incidents In and Around U.S. Waters, Calendar Year 1987 and 1983.

American Petroleum Institute, Proceedings, 1985 Oil Spill Conference.

FINAL DRAFT #23
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RELEASES FROM UNDERGROUND STORAGE TANKS:

A PRELIMINARY ANALYSIS OF ECOLOGICAL RISKS

I OVERVIEW

This paper analyses the ecological risks associated with the storage of petroleum and chemical products. The scope is restricted, however, to underground storage tanks (UST), even though petroleum and chemical products occur in other places across the country, including surface tanks, pipelines, and transportation units (trucks, shipping rail), all of which contribute to potential ecological risks. The papers focuses on USTs because of the large number of reported releases from this source and the lack of Agency attention to potential ecological risk.

This paper will describe sources, releases, types of products and constituents, proposed regulations, and state-of-knowledge about ecosystem esposure and impacts. The paper concludes that UST leaks can result in significant local ecological risk if an ecosystem is exposed, but that low risks are usually associated with leaking USTs because tanks are typically located in disturbed settings and leak product does not reach natural ecosystems. Consequently, despite a large number of leaking tanks, from a national perspective, ecological risks are ranked as low.

II DESCRIPTION OF SOURCES, RELEASES, CONTROLS AND EXPOSURES

Sources. The proposed UST regulation will apply to an estimated 1.4 million tanks -- over 95% (1,350,000) store petroleum products (half for retail sales and half for industrial usage) and about 4% (54,000) contain hazardous chemicals. An estimated 3 to 7 million tanks are currently exempted from regulation. This paper will focus on tanks that are to be regulated because of information availability.

Releases. The EPA Office of Underground Storage Tanks estimates that the number of USTs that are currently leaking is between 10-25%. This translates into 140,000-350,000 leaking tanks. Although industry-sponsored studies suggest that there are very few leaking USTs, studies and anecdotal reports from Federal, State and local governments indicate that a large number of tanks are leaking. New York's Suffolk County instituted tank testing requirements in 1980, and it appears that 20% of their 8,000 tanks were leaking. Officials in Dade County, Florida, reported the presence of petroleum in ground water at 10% of the tank sites where monitoring wells were installed. In May, 1986, a report by OPTS[1] estimated that 35% of nonfarm USTs storing motor fuel were leaking under test conditions based on a tank tightness tests of national sample.

Several EPA studies have addressed the nature and national scope of the UST problem. The OPTS study estimated the average leak rate, under test conditions, to be 0.3 gallons per hour, which could result in up to 2500 gallons per year. Another Agency study[2] completed in July, 1986 compiled information on 12,000 actual UST release incidents between 1970-1984 (three quarters of which occured after 1980). These results indicate that 33% of the incidents involved releases of 100 gallons or less, about 50% were between 100 and 2500 gallons, and 12% were between 2500 and 10,000 gallons. Less than 5% were greater than 10,000 gallons.

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[1] Underground Motor Fuel Storage Tanks: A National Survey. EPA 560/5-86-013.

Stress Agents. A wide range of commercial petroleum products are produced from crude oil, including highly refined gasolines, fuel oils, lubricants, solvents, liquified petroleum gases, building materials and petroleum coke. Petroleum products that are stored in USTs in large quantities are motor fuels (aviation gasoline, motor gasoline, diesel fuel and jet fuel), heating oils (distillate fuel oil and residual fuel oil), solvents, and automotive and industrial lubricants.

Petroleum is comprised of hundreds of compounds, primarily simple saturated and unsaturated hydrocarbons. A wide variety of compounds are added to enhance performance of the product or impart certain characteristics. These additives are often very toxic, and some cases carcinogenic. In terms of human health effects, benzene, toluene and xylene are commonly used as surrogate stress agents because of their human toxicity and mobility in the environment. Analogous surrogate indicator compounds for ecological effects have not been identified.

About 480 of the 715 CERCLA hazardous substances may be stored in USTs, but little information is available on what substances are actually being stored and in what quantities. Preliminary information indicates that six (low molecular weight organic) solvents -- acetone, methanol, toluene, xylene, methylene chloride and methyl ethyl ketone -- account for over 50% of UST chemical tanks and total volume. Pesticide formulations and inorganic compounds are also stored in USTs, but insufficient information exists to characterize this segment.

In terms of the "stress agents" identified by the Ecosystem Research Center, "oil and petroleum products" are the primary agents from leaking USTs. Petroleum UST leaks also contribute air emissions (i.e., "gaseous phytotoxicants"). Stress agents from chemical-tank leaks could include "gaseous phytotoxicants" to air; "toxic organics and toxic inorganics" to water (as well as possibly others, such as "pesticides" and "acids"); and, "toxic organics and inorganics" to terrestrial ecosystems.

Regulatory Control. Subtitle I of the Hazardous and Solid Waste Amendments (HSWA) of 1984 established a comprehensive regulatory program for "underground storage tanks." The statute defines an UST as any tank (or combination of tanks) with at least 10% of its volume below the ground, including piping, that holds a "regulated substance[1]."

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[2] A regulated substances is defined as petroleum or substances defined as hazardous under CERCLA, but excludes subtances regulated as a hazardous waste under RCRA. The Agency currently regulates about 10,000 hazardous waste tanks under RCRA.

[3] EPA. Summary of State Reports on Releases from Underground Storage Tanks. EPA/600/M-86/020. July, 1986.

HSWA excludes from regulation a number of USTs (e.g., smaller farm and residential tanks storing motor fuel for non-commercial use; building heating oil tanks; septic tanks; pipeline facilities; flow-through process tanks; tanks directly related to oil and gas production; surface impoundments), and EPA is currently studying these excluded tanks to determine if the regulated universe should be expanded. EPA is considering an UST regulation with the following elements:

New Tanks:	o Corrosion-protected single-walled tanks with frequent-to-continuous leak detection
Existing Tanks:	o Mandatory retirement or upgrade to new tank standards within in years
	o Periodic tank testing (or other leak detection system) in interim (bare steel every three years; corrosion-protected tanks every five years)
Chemical Tanks:	o Secondary containment for new tanks with variance based on leak detectability of substance stored
	o Mandatory retirement and leak detection for existing tanks on same schedule as petroleum tanks
Corrective Action:	o Site-by-site assessment approach

These new regulatory controls are expected to significantly reduce the UST environmental problems. Secondary containment for new chemical tanks may reduce the likelihood of releases to nearly zero. The corrosion protection requirements and leak detection requirements for petroleum tanks will significantly reduce the number of releases, as well as the size of releases that do occur. Overall, the effect of new Federal regulations, in concert with emerging state program capabilities, is predicted[4] to reduce the UST problem (i.e., using a surrogate measure — "plume -acres avoided") by more that 90%. The leaks that do occur will be assessed on a site-specific basis to determine appropriate cleanup requirements.

For this analysis of ecological risks, it is reasonable to assume that the baseline conditions take into account a 90% problem reduction gained by anticipated future UST regulation.

Exposure. The geographical distribution of tanks correlates, at a national scale, with human population density. Therefore, most tanks are located in urban areas where the natural ecosystems have already been significantly altered. Thus, UST leaks that result in exposure to natural ecosystems are rare relative to the total number of leaks. However, given the number of tanks and the high leak rate (up to 25%), the cumulative ecosystem exposure nationwide could be significant.

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[4] Unpublished analysis by the EPA office of Underground Storage Tanks.

A leaking UST can be considered to be a point-source discharge having two different transport pathways — liquid and vapor. Discharges are usually to the soil (but can be directly to groundwater where a tank is located in groundwater) and contaminants can be transported to ground water, surface water and the air.

In terms of the liquid phase, movement of the product is a function of the quantity and physical properties (solubility, specific gravity, viscosity, evaporation rate, etc.) of the contaminants and the environmental conditions of the site (location of the ground water table, structure of the subsurface soil and rock, proximity to surface water, etc.). Transport of the contaminant in the unsaturated zone is characterized by vertical flow driven by gravity and lateral speading. Because of viscosity differences, heavy oils do not readily penetrate the soil, whereas lighter products like gasoline move through the soil more quickly than water. In general, the contaminant plume will take on a pear-shaped form as it moves through the unsaturated zone, but the shape can be irregular. If the plume reaches groundwater, dissolvable substances (e.g., benzene) will enter the groundwater and be transported in the direction of the groundwater flow. Immiscible (nondissolvable) substances that are "lighter" than water will build up as a floating plume on the ground water surface, and denser immiscible substances will sink.

Much less is known about vapor-phase transport. A liquid contaminant leaking from an UST will enter the vapor state (evaporate) according to its vapor pressure, and will move predominately downward and horizontally.

Impacts. Few ecological impacts from leaking underground storage tanks have been reported, but this may be due, in part, to the lack of proper examination. The OUST release incident survey[3] showed that in most cases health or environmental impact were not documented. Of those sites that did report an impact, about 10% identified damage to the immediate ecosystem in the form of damage to aquatic life, wildlife, plant life, or crop loss, as follows:

Reported impacts	No. Cases
Damage to aquatic life, wildlife, plants, crops	317
Contamination of drinking water supplies *	827
Contamination of other surface and ground waters	445
Human illness and death	113
Fire and explosion, and threat of fire and explosion	1,110
Other	216
Total	3,028

*Including private and public wells and potable surface waters

UST releases, which include surface spills and subsurface leaks, are reported to affect these media: soil (77%), ground water (53%), surface water (22%), and air (16%) — note that several media can be affected by a single release.

In many cases, the immediate zone around the storage tank assimilates the release without offsite damage to the environment or human well being. Although many factors affect the transport and fate of petroleum and hazardous substances, most releases are confined to the soil in the immediate area, which invaraibly has been altered previously by other human activities. Furthermore, most releases to ground water are also confined to a relatively small area (in some cases, however, contaminated ground water, or release material itself, has entered terrestrial and aquatic ecosystems. Significant ecological impacts are rare, and are a largely a function of the volume and site-specific location of a release. Although, impacts on ecosystems have been little noted, the long-term imparts and the high frequency of low-level releases could have serious impacts.

Although the leaking UST problem has emerged recently as an environmental problem, a considerable body of knowledge exists about the impact of oil pollution on marine and estuarine ecosystems. Severe localized damages - such as immediate decimation of fishes, shellfish, worms, and seabirds at the site of a spill have been well studied. Whereas immediate death to marine birds often occurs as a result of damage to feathers and death to fishes as a result of clogged gills, the toxic compounds in petroleum can also result in more complex impacts, including nonlethal effects and transport of toxicants through food chains. Long-term effects, such as loss of reproductive capability in surviving mussels and alternative of the feeding behavior of lobsters, have been shown to last for up to 10 years after an event. In addition, detergents used in clean-up operations have also been shown to have toxic effects.

In water, most petroleum compounds evaporate, oxidize or degrade as a result of bacterial action. Some dissolve, some settle or accumulate tar balls, some become surface films and some enter organisms.

Biodegradation of Petroleum. Petroleum is a naturally occuring substance, and as might be expected, many of its constituents can be degraded by biological activity. In terrestrial ecosystems, degradation in most prevalent in the unsaturated zone where conditions are most favorable for microbial activity. Degradation is microorganism-specific and dependent on available oxygen and other environmental factors at a site.

The hydrocarbon fraction of petroleum products is most amenable to bacterial action in favorable conditions, but the fate of petroleum additives is less certain. Petroleum additives (e.g., anti-foam, anti-knock, anti-corrosion, deicers, detergents, octane improvers, friction rodifiers) are quite numerous, particularly for motor fuels, and can be present at concentrations ranging from a few parts per million to as much as 10% by volume. Many petroleum additives are hazardous substances and therfore their presence is important when addressing the evironmental significance of UST leaks. Identifiable petroleum additives that are also on the list of hazardous substances stored in UST's include tetraethyl lead, ethylene dibromide, ethylene dichloride, dimethyl amine, and methanol.

III PROBLEM EVALUATION

Based on the information presented in this paper, Figure 1 contains a proposed ranking of ecological effects from leaking USTs. The overall ecosystem effects of leaking USTs is rated low for two reasons: most USTs are located in or near severly disturbed or previously destroyed natural areas; and, although leaks from both petroleum and chemical USTs can result in significant local ecological effects if an ecosystem is exposed, most releases (spills and tank system leaks) do not move very far from the point of discharge and do not result in significant ecosystem exposure. Exceptions do occur but are restricted to USTs in areas with a high groundwater table or where surface waters are adjacent to releases. The only documented ecological impacts are very local effects on adjacent terrestrial systems and on aquatic systems (e.g., fish kills in streams). The air-transport route for VOC's and the contribution to air quality degradation have not been well characterized.

The regulatory controls that will be implemented over the next decade, together with emerging problem awareness in state and local governments, will significantly reduce the future potential for ecological disturbance. The present regulatory focus addresses the potential impacts on drinking water supplies, and the immediate threats of fire and explosion from leaking USTs. Potential ecological risks will probably largely be avoided as a indirect benefit of addressing the human health impacts.

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Figure 1. Proposed Ranking of Ecological Risks from Leaking Underground Storage Tanks.

Ecosystems		Intensity of Ecological Effects[5]	Reversibility of Impact[6]	Exposure[7]	Total Ecological Risk
Freshwater	Buffered lakes	H	M	L	L
	Unbuffered lakes	H	M	L	L
	Buffered streams	H	M	L	L
	Unbuffered streams	H	M	L	L
Marine and estuarine	Coastal	H	M	L	L
	Open ocean	L	L		?
	Estuaries	H	M	L	L
Terrestrial	Coniferous forest	–		L	L
	Deciduous forest	–		L	L
	Grassland	–		L	L
	Desert/Semi-arid	–		L	L
	Alpine/Tundra	H	H	L	L
Wetland	Freshwater - isolated	M	M	L	L
	Freshwater - flowing	M	M	L	L
	Saltwater	M	M	L	L

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[5] The significance of ecological effects of an UST release that occurs in or reaches a particular ecosystem type.

[6] The time required for ecosystem recovery after an UST release (L = 1 year; M = 10 years; H = 100 or more years)

[7] At a national scale, the expected exposure of different ecosystems to UST releases.

Other Sources of Ground-Water Contamination #24

Over 200 contaminants have been identified in ground water. This contamination results from a wide variety of point and non point sources that encompasses every day activities ranging from waste disposal practices to road de-icing. Should ground water contaminated by these sources discharge into an aquatic or wetland ecosystem, there is the potential for organisms and chemical processes to be affected. This paper discusses the ecological risks posed by contaminated ground water.

For the purposes of this paper ten sources of contamination have been grouped and identified as "other sources of ground-water contamination". These categories are : septic tanks and cesspools, class V injection wells, waste water spray irrigation, material stockpiles, pipe lines, irrigation practices, non point discharges to ground water, production wells, salt water intrusion, and oil production holding ponds. Stress agents released from these " other sources of contamination include: toxic organics, pesticides, toxic inorganics, nutrients, microbes, acids, oil and petroleum products. Specific contamination incidents,such as selenium contamination from irrigation return flows at Kesterson Reservoir have resulted in fish and water fowl deaths, genetic abnormalities and reproductive problems verify the potential for severe local effects.

These ten sources number in the millions and are distributed throughout the United States. Therefore the potential for ground-water contamination and subsequent ecological risk could be enormous. This ecological risk is somewhat tempered because the ecological impacts groundwater contamination are quite site and time specific. Additionally, an impact can only occur if contaminated ground-water discharges into an ecosystem and if there is a sufficient volume and concentration to impact the biological or chemical components of the system. In general,only aquatic and wetland ecosystems will be directly impacted from contaminated ground water. Filtering properties of soil and the dilution and dispersion properties of streams, lakes, and bays can also reduce the ecological risk posed by contaminated ground water. Unfortunately data does not exist to verify total number of incidents on a regional, national, or global level making it impossible to determine the actual versus potential risk is from these sources.

This environmental problem has been given an overall ecological risk rating of medium. Even though the ecological impacts from these sources are mainly at an ecosystem level the number of such sources are large and therefore the potential risk is high. A more complete data base detailing the level and location of ground-water impacts is needed to verify the magnitude and extent of the ecological risks from other sources.

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INTRODUCTION

Over 200 contaminants have been identified in ground water. (Stone et al., 1984) These include a variety of metals, toxic organics, toxic inorganics, pesticides, herbicides, radionuclides, and microbes. Incidents of contamination have been documented in every state, often occurring near industrialized, heavily populated areas. Should contaminanted ground water be discharged into an ecosystem, severe local impacts could occur.

Ground-water contaminants are released from a wide diversity of point and non point sources. A 1984 OTA report "Protecting Our Nation's Ground Water From Contamination" (Stone et al. 1984) identified 33 major categories of ground-water contamination sources. For the purpose of the comparative risk study, ten categories of ground-water contamination sources have been grouped together and are identified as "other sources of ground-water contamination". These are:

Septic Tanks and Cesspools

Class V Injection Wells

Land application of nonhazardous waste and nonsludge material (waste water-spray irrigation)

Material stockpiles (non waste)

Pipelines (hazardous and non hazardous waste)

Irrigation practices (irrigation return flows)

Nonpoint discharges to ground water(fertilizer application, animal feeding operations, deicing salt applicaions, urban runoff, etc.)

Production wells (oil and gas, geothermal and heat recovery wells water supply wells, etc.)

Salt Water intrusion

Oil production holding ponds

This list focuses on those sources which because of their number, general locations, or the type of contaminants released are likely to pose an ecological risk. These "other sources of ground-water contamination" number in the millions and are distributed though out the United States. Additionally, sources are everyday practices such as road salting, fertilizer application etc. Therefore, the potential for ground-water contamination and subsequent ecological impact is enormous. It should be emphasized however, that ecological impacts caused by ground water are very site and time specific. Extent of impact is greatly influenced by such factors as: contaminant concentration, volume of discharge, and proximity of the source to the point of discharge.

The only time there will be an ecological impact from an "other source of ground-water contamination" is when the contaminated ground water surfaces from an aquifer via a discharge point. Thus even though ground water at a particular site may be contaminated enough to pose human health risks if consumed, it will not pose an ecological risk until it exits the aquifer into an ecosystem, and plant and animal communities are exposed to the contaminants. The contaminated ground water can be considered the stress agent which can cause several types of ecological impacts including: changes in biotic community structure, changes to ecological processes, and the elimination of species particularly important to humans. Since aquatic and wetland ecosystems are usually discharge areas, they are the ecosystems the most susceptable to impacts from contaminated ground-water.

Several examples of documented ecological impacts from "other sources of ground-water contamination" are listed below: Nitrates from both septic tanks and agrichemicals can cause eutrophication and algal blooms in lakes. Brines discharged from oil operations have resulted in numerous fish kills in Pa, W.V., N.Y. and several midwestern states. An additional effect associated with brine contamination is landscaring which results in the stunting and death of trees and grasses along stream banks where ground water is discharged. Finally selenium leached out of the soil by irrigation return flows have resulted in waterfowl kills and genectic abnormalities.

No compilation of ecological impacts from ground water contamination or an analysis of the national scope of such incidents exists at this time. This problem may never be documented due to the prohibitive costs associated with collecting such data.

SOURCES, STRESS AGENTS AND EXPOSURES

SEPTIC SYSTEMS

Stress Agents - nutrients, toxic inorganics, microbes, toxic organics.

Potential for Exposure - It has been estimated that there are 22 million domestic domestic septage systems in the United States. A 1983 report indicates that these systems release between 820 and 1460 billion gallons of waste annually.It is is estimated that 25,000 industrial septage systems discharge between 1.2-1.9 billion gallons of waste annually (OTA 1984).

Geographic Variability - The highest regional densities of use are in the eastern third of the country and along portions of the west coast (OTA 1984)

Ecosystem Exposures - streams, lakes, estuaries and wetlands, frequency and duration unknown.

Controls - local ordinances and state laws: regulation is variable.

Information Completeness - poor

CLASS V INJECTION WELLS (only Class V wells are discussed because of regulatory programs in place to prevent contamination from Class I, II, III and IV wells.

Types - Drainage Wells (a.k.a. Dry Wells), Geothermal Reinjection Wells, Domestic Waste Water Disposal Wells, Mineral and Fossil Fuel Recovery Wells, Oil Field Production Waste Disposal Wells, Industrial/Commerical Disposal Wells, Recharge Wells, and miscellaneous wells.

Stress Agents - pesticides, herbicides, nutrients, microbes, acids, oil and petroleum products, thermal pollution, toxic organics and toxic inorganics.

Potential for Exposure - There were approximately 116,150 class V wells in operation as of March 1986 (EPA 1986). The ones with most potential numerically and volumetrically to contaminate ground water are drainage wells. The most common of these wells are: agricultural drainage wells (950), storm water and industrial drainage wells (54,000 combined) (EPA 1986).

Geographic Variability - Agricultural drainage wells are most common in IA, ID, TX and CA. Industrial drainage wells are present mainly in: NY and NJ, Storm water drainage wells are used most often in the western states. They are most frequently found in Washington, Oregon and Arizona.

Ecological Exposures - unknown

Controls - a permit is authorized by rule. Generally there are not specific requirements, but in individual cases where wells impact a drinking water supply permit holders might be required to monitor etc.

Information Completeness - poor

LAND APPLICATION (WASTE WATER)

Stress Agents - nutients and toxic inorganics (heavy metals)

Potential for Exposure - 485 POTW's using spray irrigation were in operation or under construction in 1982 (OTA 1984)

Geographic Variability - unknown

Ecological Exposures - unknown

Controls - In general no NPDES permits are required and this source falls into a state's nondischarge category. Operators must meet state requirements. For EPA grant supported projects, the owner must delineate the boundary of system install monitoring wells, and take samples to ensure no ground-water contamination as a condition of the grant award.

Information Completeness - poor

MATERIAL STOCKPILES

Stress Agents - Descriptive material is rare. Toxic inorganicas.

Potential for Exposure - Approximately 700 million tons of the 3.4 billion tons of material produced annually are stockpiled. Descriptive material is rare and was acquired for only coal production. Coal stockpiles at utilities contained approximately 185 tons in 1980 (OTA 1984).

Geographic Variability - unknown

Ecological Exposures - unknown

Controls - none

Information Completeness - poor

PIPELINES

NON-WASTE

Stress Agents - oil and petroleum products, toxic inorganics, and inorganic acids.

Potential for Exposure - In 1976 approximately 175,000 miles of pipeline carried 9.63 billion bbls of petroleum per year in the USA. In 1981,239 pipeline failures were reported,with 214,384 bbls lost. Of these leaks crude oil was involved in 48.1% of the failures. Gasoline in 19.3% of the failures, liquified petroleum gas in 14.6% of the failures,natural liquid gas in 5% of the failures, and fuel oil in 4.6% of the failures (OTA 1984)

Geographic Variability - unknown

Ecological Exposures - unknown

Controls - not regulated by EPA

Information Completeness - poor

NONPOINT SOURCES

IRRIGATION RETURN FLOWS

Stress Agents - salts, pesticides, herbicides, and nutrients

Potential for Exposure - 51 million acres were irrigated in 1978. Approximately 169 million acre-feet of water were used for irrigation in 1980 (OTA 1984).

Geographic Variability - Irrigation is most common in the West, the Central and Southern Plains, Arkansas, and Florida (OTA 1984)

Ecological Exposures - lakes, streams and wetland. Frequency and duration of the exposure unknown.

Controls - none

Information Completeness - poor

FERTILIZER APPLICATION

Stress Agents - nutrients

Potential for Exposure - In 1982-83 farmers used 42.3 million tons of commercial fertilzers. Fertilizers used in 1981-82 contained 11.1 million tons of nitrogen,4.8 million tons of phosphates, and 5.6 million tons of potash. In 1978 approximately 229 million acres were treated with commercial fertilizers and 17 million acres were treated with lime (OTA 1984)

Geographic Variability - The five states using the most fertilizer between 1981-1983 were: Illinois, Iowa, California, Indiana, and Texas (OTA 1984).

Ecological Exposures - lakes, streams and wetland. Frequency and duration of the exposure unknown.

Controls - none

Information Completeness - poor

ANIMAL FEEDING OPERATIONS

Stress Agents - nutrients and microbes

Potential for Exposure - It is estimated that all livestock on feedlots and farms produce 175 million dry tons of manure annually and that 90% of it is returned to the land (OTA 1984).

Geographic Variability - Feedlots are located primarily in the Corn Belt and the High Plains (OTA 1984).

Ecological Exposures - lakes, streams and wetland. Frequency and duration of the exposure unknown.

Controls - surface discharges NPDES, ground water unknown

Information Completeness - poor

DE-ICING SALTS APPLICATIONS

Stress Agents - salts and toxic inorganics

Potential for Exposure - In the winter of 1982-83 an average of 15.5 tons of dry salts and abrasives and 2.9 gallons of liqiud salts were applied per lane per mile of road (OTA 1984).

Geographic Variability - Confined to the snow belt especially the populous ares of the Northeast Midwest (OTA 1984).

Ecological Exposures - lakes, streams and wetland. Frequency and duration of the exposure unknown.

Controls - some states and locals regulate application rates

Information Completeness - poor

URBAN RUNOFF

Stress Agents - toxic inorganics and toxic organics, nutrients microbes and petroleum products.

Potential for Exposure - 21.2 million urban acres contributed to stormwater runoff in 1970.This figure is projected to increase to 32.6 million acres by the year 2000 (OTA 1984)

Geographic Variability - concentrated in urban areas

Ecological Exposures - lakes, streams and wetland. Frequency and duration of the exposure unknown.

Controls - new Federal regulation for industiral run off. Local run off controlled by municipal ordinances.

Information Completeness - poor

PRODUCTION WELLS (Oil, geothermal and heat recovery, and water supply)

Stress Agents - toxic inorganics and toxic organics

Potential for Exposure - Approximately 548,000 oil wells produced an estimated 3.1 billion bbls of crude oil in 1980. More than 370,000 irrigation wells are used to supply approximately 126,000 farms in the United States (OTA 1984).

Geographic Variability - Oil wells are clustered in the Southwest, Alaska, Louisiana, Wyoming, and the MidWest. Geothermal activities are primarily in the West and the heavily populated northern states where the use of earthcoupled heat pumps is increasing. It is estimated that the greatest number of water supply wells are in the Southwest, the Central Plains,Idaho and Florida. (OTA 1984).

Ecological Exposures - unknown

Controls - state permits

Information Completeness - poor

SALT WATER INTRUSION (over drafting)

Stress Agents - salt

Potential for Exposure - Approximately 21 billion gallons of ground water are withdrawn in excess of recharge capacity daily. This is 26% of all ground water withdrawn (OTA 1984).

Geographic Variability - Excess overdraft occurs mainly in coastal areas(California, Texas, Louisiana, Florida, and New York), the Central Plains, and the Southwest (OTA 1984).

Ecological Exposures - unknown

Controls - Municipal caps on pumping rates

Information Completeness - poor

EVALUATION

The overall potential ecological risk associated with "other sources of ground-water contamination" is enormous because of the large number of sources and the lack of strict regulatory programs for many of them. This threat is somewhat tempered because ecological impacts occur only when ground-water contaminated by these sources is released from an aquifer in sufficient volume and concentration to effect organisms or chemical processes. Additionally, the filtering properties of soils and the dilution and dispersion process of streams, estuaries, coastal waters and lakes can also reduce ecological and risk posed by ground-water contaminants. Finally, although ecological risk from contaminated ground water can be quite high at the ecosystems level, data does not exist which enables one to determine the total number of incidents on a regional, national or global level making it impossible to verify what the actual risk is compared to potential risk.

If all "other sources of ground-water contamination" are combined, the stress agents released into aquatic and wetland ecosystems consist of toxic organics, pesticides, toxic inorganics, nutrients, microbes, acids, oil and petroleum products. All these stress factors, with the exception of nutrients, have been rated as having a high ecological effect on all types of fresh-water ecosystems and estuaries. These are the systems in which you would expect the greatest risk from "other sources of ground-water". For wetlands, Cornell rated these stress agents as medium to high. Specific contamination incidents such as Kesterson Reservoir, where irrigation return flow caused selenium to leach into a wildlife refuge which resulted in waterfowl deaths and genetic abnormalities, verify the severe local impact contaminated ground water can have. BLM (1986) indicates that the potential for 100's of such sites exist throughout the country. However, one must also consider that septic tanks, the most common type of other source of ground water contamination both in number and discharge volume of release mainly nutrients which Cornell ranked as causing medium risks to most ecosystems.

Based on Cornell's analysis of stress agents, the number and distribution of sources, documented incidents and likelihood of discharge to ecosystems. I ranked risk from "other sources of ground-water contamination" as medium for all aquatic and wetland ecosystems and estuaries. Coastal waters and terrestrial ecosystems would be ranked low. The latter has been included as low because contaminated springs could impact terrestrial animal populations drinking the spring water.

I also suggest a medium overall rating because even though the ecological impacts from this source are mainly at an ecosystem level, data does not exist to determine the number of such local incidents occurring nationally.

BIOLIOGRAPHY TO DATE

ICF Incorporated 1986. Analysis of the Definition of Ecologically vital Ground Water Under the Proposed Ground-Water Classification Guidelines., Washington D.C.

Stone,Paula J., Joan Harn, Howard Levenson, Francine Rudoff 1984. Protecting the Nation's Ground Water from Contamination. OTA. Washington D.C.

Pesticides: Comparative Ecological Risk

Part I

Approximately 50,000 pesticide products, derived from about 600 basic chemical ingredients, are registered for use by EPA. About 3.5 billion pounds of formulated pesticide products (1.2 billion pounds of active ingredients) are used each year - 79 percent by agriculture, 15 percent by industry, and 6 percent by households. Farmers are the biggest users of pesticides, accounting for about two-thirds of all pesticides used.

As a class, pesticides are at the same time among the most beneficial and the most hazardous of substances. Agriculture depends upon pesticide products to protect crops from insects, mildew, plant disease, and other pests. Health officials need them to control the spread of diseases carried by mosquitoes and other insects. On the other hand, because pesticides are designed to kill living organisms, unintended exposure to them can be very destructive, especially to biotic receptors (e.g., fish and wildlife) in the agroecosystem.

The agroecosystem (e.g., croplands, range and pasture land, forested areas) is very important in that it produces the bulk of the food used for human consumption and it also produces the preponderance of our fish and wildlife (ODUM, 1971). The small field agricultural systems of the upper Midwest and South, characterized by small agricultural fields bordered by strips of brushy habitat, are ideal for "growing wildlife" because of the larger amount of edge or ecotone which is important for maintaining ecological diversity. Thus, this agroecosystem is very important because it produces our food and maintains to some extent, ecological diversity. Unfortunately, the use of pesticides to increase food production puts fish and wildlife at risk.

Most of the agroecosystem in the United States is treated with pesticides at least once per growing season; in many instances there are multiple applications throughout the year. Pesticide-treated crops are grown in just about all biomes: e.g., grain and alfalfa in deserts; gardens in the tundra; lumber in boreal forests. The aquatic portion of the agroecosystem is directly treated with pesticides (e.g., aquatic herbicides, mosquito larvicides) and also receives agricultural runoff laden with pesticides. These freshwater systems ultimately lead to coastal and estuarine systems which can become contaminated with pesticides. In addition, coastal and estuarine systems receive direct input from many uses of pesticides (e.g., use of TBT in antifouling paints).

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Fish and wildlife are directly exposed to pesticides through inhalation, ingestion, and dermal absorption. Residues on food - plants, seeds, insects, earthworms, smaller organisms and water - and in their habitat result in direct exposure to pesticides. Certain pesticides bioaccumulate and contaminate food chains.

These exposures lead to direct effects on nontarget organisms. Acute poisonings lead to direct mortality or cause a decreased ability to function leading to mortality from some other cause (e.g., predation). Exposure can cause chronic effects like decreasing the ability of an animal to function normally (e.g., foraging behavior, breeding behavior, thermoregulation) or cause reduced reproductive success. Certain pesticides (e.g., herbicides and rodenticides) cause habitat degradation via loss of the plant and animal food base. These types of effects on individual organisms within systems can cause effects on the system itself. These effects can induce a reduction or alteration of species diversity, impact on food chains which can alter energy flow and nutrient cycling, reduce habitat quality and the alteration of physical resources via degradation of air, water, and soil qualities, and impact on the stability and resiliency of the agroecosystem.

Part II

Source Terms

For water and terrestrial sources, the definition given to the stress agent - pesticides and herbicides - has a significant impact on whether a particular ecosystem is affected by the stress agent from an ecological viewpoint.

Water Source

Pesticides and Herbicides include agricultural biocides that are applied directly, exported (via surface water runoff), and transported via drift from target agroecosystems.

OPP data (NPIRS) indicate that there are at least 121 pesticide active ingredients registered for direct application to streams, lakes, ponds, estuaries, and coastal ecosystems. The definition also does not address direct impact of pesticides and herbicides to aquatic ecosystems due to drift from terrestrial agroecosystems. OPP estimates that approximately 10 percent of the amount of a pesticide or herbicide applied via air or mist blower ground equipment will reach adjacent aquatic ecosystems (EPA-540/9-86-167, p. 20). The drift source can have significant impact on the biota in the ecosystem (Nigg *et al.*, 1984). Further, when pesticides and herbicides are applied via air to forest ecosystems, there is an unavoidable direct application to aquatic ecosystems such as small streams, ponds, and estuaries. Approximately 137 pesticide active ingredients are registered for application to forest ecosystems (NPIRS).

Terrestrial Source

Pesticides and Herbicides include applications directly to terrestrial ecosystems or by drift from agricultural applications; transport by surface and groundwater systems are considered elsewhere.

The "agroecosystem" is an important ecosystem which can be significantly affected, not only by land use changes, but also by manipulation, e.g., the use of pesticides and herbicides. "Perhaps no human activity has a more profound impact on American wildlife than has agriculture. Today 20 percent of the continental United States is in cropland, and another 25 percent is in pasture" (Wildlife and America 1978:89). "The agricultural and forest industry is the largest modifier of the lands and water that provide habitats for fish and wildlife. The size, scope, and nature of agricultural practices such as cultivating cropland, grazing rangeland, and harvesting forests have profoundly affected the quality of these habitats (National Research Council 1982:xv). Further, "Agricultural activities on cropland, rangeland, pasture, and forest land have been altering wildlife habitat, in both positive and negative ways, throughout America's history" (Ibid:3). "Croplands [are] the most intensively managed of all agricultural lands and the most ubiquitous habitat type . . . Even though croplands are no longer pristine areas, however, all but the most intensively manipulated are capable of supporting some wildlife" (Ibid:92).

Thus, the terrestrial agroecosystem today is very important from an ecological viewpoint both from the fact that cropland, pastures, and rangeland occupy a large percentage of the U.S. land area, and from the fact that the agroecosystem provides important habitat for the preponderance of our wildlife species. Further, pesticides are used to the greatest extent on this ecosystem. While approximately 33 pesticide and herbicide active ingredients are currently registered and applied directly to rangelands, the large majority of the 600 pesticide and herbicide active ingredients are registered for use and applied directly to croplands (NPIRS). OPP also found that at least 137 pesticide and herbicide active ingredients are applied directly to forest ecosystems (NPIRS).

What does this say about the potential effects of pesticides and herbicides on terrestrial ecosystems such as the agroecosystem, forest, rangeland? Following are a few case studies that show ecological effects on the biotic components of terrestrial ecosystems, specifically avifauna, from pesticides. (1) Diazinon is a broad spectrum pesticide used to control a variety of insects on a variety of sites including agriculture, grassy areas such as golf courses and sod farms, ornamental nurseries, around commercial establishments, and homes and gardens. EPA received approximately 86 bird kill reports from at least 18 States. This included data on the potential reduction of a local population of Atlantic Brant Geese. Further, in consultation with the Fish and Wildlife Services' Office of Endangered Species, EPA concluded that two endangered species would likely be jeopardized by the use of diazinon on grassy areas such as golf courses and sod farms: the Hawaiian Goose (Branto sandvicensis) and the Mohave Tui Chub (Gila ficolor Mohavensis). After careful review by EPA, diazinon use on golf courses and sod farms was cancelled by EPA on September 24, 1986 based on data that show exposure to diazinon applied on these sites results in unreasonable risk to birds. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel supported EPA's action [see the following EPA Documents: EPA Environmental News, September 24, 1986; FR Notice (OPP-30000/47A); Diazinon Support Documents, OPP, December 1985]. (2) Field data indicate that black-billed magpies (Pica pica) were killed by the pesticide famphur used as a pour-on to control cattle workers (Hypoderma sp). The magpie population decline that occurred throughout most of the western pastureland areas was temporarily correlated with the appearance of famphur as a cattle grub treatment (Henny et al., 1985). (3) In 1975, vast areas of New Brunswick (Canada) forests were sprayed with combinations of the pesticides phosphamidon, fenitrothion, aminocarb, and trichlorofon to control spruce budworm. The direct sprays to the upper canopy resulted in total bird mortality of greater than 3 million. The dead birds represented 26 species in six families, with Parulidae being well represented since warblers numerically comprise 50 to 65 percent of the avifauna complex of the forest stands sprayed. The data support the conclusion that songbird populations were adversely affected in the sprayed areas comprising approximately 2.7 million ha in New Brunswick alone (Pearce et al., 1976). (4) EPA has recently initiated a Special Review of the pesticide carbofuran in its granular formulation. Based on a large volume of scientific data reviewed by the Agency, EPA has concluded that granular carbofuran is highly toxic to avian wildlife and its use results in significant fatalities of many small species of birds and also secondary poisoning of birds of prey. Carbofuran is a major pesticide used primarily on corn. Annual domestic usage was estimated at 10 to 11 million pounds active ingredient; approximately 60 percent used on corn; 20 percent on sorghum; in 1982, approximately 82 million acres were planted in corn for all purposes (USDA, 1983 Agricultural Statistics). In addition, the Agency has supporting data to conclude that the use of carbofuran can reasonably be anticipated to at least contribute to significant local, regional, or national population reductions in some bird species, especially birds of prey and endangered species [See FR Notice (OPP-30000/48) Carbofuran; Special Review of Certain Pesticide Products].

Summary

Based on the above information concerning the effects of pesticides on the terrestrial ecosystem, OPP believes that (1) agricultural land (including cropland, pasture, and rangeland) should be included in any list of terrestrial ecosystems; (2) the potential scale of effect and detail of terrestrial ecosystem-level effects for pesticides and herbicides under terrestrial sources is high; (3) ecological effects from direct application and drift can be very significant over extensive areas of forests, agricultural lands, and grasslands, with important ecological effects primarily involving biocides affecting nontarget organisms at the population level. Effects at the community level are also possible.

Part III

Summary of Ecological Effects From Pesticides:

Ecosystems

A. Freshwater

Streams

- There are approximately 31 active ingredients applied directly to streams for pest control and stream management. These are highly toxic pesticides.

- Streams will receive direct application of toxic pesticides for forest sprays (approxiamtely 137 active ingredients).

- Significant runoff impact on streams from highly toxic and somewhat persistent pesticides used on agricultural crops, from grains, vegetables, fruits, nuts, etc.

Lakes

- Approximately 55 active ingredients are applied to lakes for pest control and lake management. These are highly toxic pesticides.
- Usually only small portions of the lakes are treated.
- The runoff impact is similar to that for streams except that the dilution factor is much greater for lakes.
- Portions of lakes will receive direct sprays (drift) from pesticide applications to forests.

B. Marine and Estuarine

Deep Oceans

- No direct pesticide applications.
- Direct discharge of some biocides from ships.
- Great dilution factor.

Coastal Waters

- Few direct pesticide applications (21 active ingredients registered for application to beaches - moderately toxic).
- Direct discharge of highly toxic and relatively toxic pesticides like TBT and Cu (antifouling paint persistent, and cooling towers); PCP and

other biocides from cooling tower direct discharges; offshore drilling and ship discharges of biocides.

- Presence of productive mollusc and fishery beds.
- Runoff from agricultural lands but filtered through estuaries and tidal wetlands.
- Large dilution factor.

Estuaries and Tidal Wetlands

- Direct application of highly toxic insecticides and herbicides (35 active ingredients) for uses like mosquito control, plant growth control.
- Direct discharge of pesticides from cooling towers, antifouling paint use, wood preservatives, etc.; pesticides like TBT, Cu, PCP are highly toxic to persistent.
- Direct runoff of highly toxic and persistent pesticides used on agricultural lands (e.g., rice, soybeans, cotton, truck farms, etc.).
- The only difference between estuaries and tidal wetlands might be their flushing rates with estuaries having more and tidal wetlands less. The difference is not considered significant in this analyis.

C. Terrestrial

Agricultural Land

- Direct application of the most highly toxic and persistent insecticides, herbicides, and fungicides.
- Multiple applications, especially during the growing season(s).
- Primary hazard to terrestrial organisms (especially birds); but runoff and drift poses a hazard to aquatic organisms.
- The number of active ingredients would be greatest in this category.

Deciduous and Coniferous Forests

- Direct application of highly toxic pesticides for forest pest control.
- Both terrestrial (especially upper canopy) and aquatic organisms (small streams) will be exposed.

- Herbicides used in forest management practices.

- Approximately 137 pesticide active ingredients can be applied to forests in general.

Grasslands (Nonagricultural)

- Direct application of highly toxic and somewhat persistent insecticides and herbicides to control pests.

- Usually no more than 1 to 2 applications per treatment.

- About 33 active ingredients were found for direct applications to rangelands alone.

- Primary concern is for terrestrial organisms.

- Runoff and spray drift will expose aquatic organisms.

Desert/Semiarid

- Few chemicals applied directly to deserts; some for rangeland pest control would be also applied to desert fringes; mostly herbicides.

- Little runoff.

- A lot of semiarid land irrigated and turned into productive agricultural cropland and pasture. In this case, comments on agricultural land would apply here also.

Tundra

- Few direct pesticide applications.

- Exposure limited to aerial transport and some limited runoff.

- Localized use of pesticides and herbicides.

D. Wetland

Wetlands

- Direct application of highly toxic insecticides and herbicides for uses like mosquito control, plant growth control.

- Runoff and drift from agricultural pesticide use which include highly toxic and persistent insecticides, herbicides, and fungicides.

- Aquatic organisms will likely receive greatest impact; some impact on terrestrial organisms.

- Moderate dilution.

Literature Citation, Data Sources

Council on Environmental Quality. (1978) Wildlife and America, Howard P. Brokaw, Ed. 532 pp. U.S. Gov. Printing Office, Washington, D.C.

Henny, C.J.; Blus, L.J.; Kolbe, E.J.; Fitzner, R.E. (1985) Organic phosphate Insecticide (Famphur) Topically Applied to Cattle Kills Magpies and Hawks. J. Wildl. Manage 49(3):648-658.

National Research Council. (1982) Impacts of Emerging Agricultural Trends on Fish and Wildlife Habitat, National Academy Press, Washington, D.C. 303p.

Nigg, H.L.; Stamper, J.H. Queen, R.M.; Knapp, J.L. (1984) Fish Mortality Following Application of Phinthoate to Florida Citrus. Bull. Environ. Contam. Toxicol. 32:587-596.

NPIRS, National Pesticide Information Retrieval System.

Odum, E.P. (1971) Fundamentals of Ecology, Third Edition, W.B. Saunders Company, Philadelphia, London, Toronto. 574 p.

Pearce, P.A.; Peakall, D.B.; Erskine, A.J. (1976) Impact on Forest Birds of the 1975 Spruce Budworm Spray Operation in New Brunswick. Progress Notes, No. 62, March 1976, Canadian Wildlife Service, 7p.

U.S. EPA. (1986; June) Hazard Evaluation Division Standard Evaluation Procedure - Ecological Risk Assessment. Office of Pesticide Programs, Washington, D.C. 20460. EPA-540/9-86-167.

USDA. (1983) Agricultural Statistics.

More than seven thousand new chemicals have been developed for industrial uses in the United States since 1979. At least half of them are believed to be in production currently and available through regular commercial markets. While manufacturing and processing procedures and use and disposal practices associated with industrial chemicals result in accidental as well as planned releases to the environment, less than 10 percent of those chemicals have been subjected to even minimal laboratory testing to assess their toxicity to aquatic and terrestrial life.

While data on the subject have not been assembled, it appears that most environmental releases of industrial chemicals from manufacturing and processing operations occur through point source discharges to receiving streams, directly or following some level of treatment in a POTW. Point source discharges also appear to be the main origin of environmental releases of industrial chemicals from use sites, although certain use and disposal practices may result in some non-point source releases. Atmospheric releases also are possible during manufacturing, processing, use and disposal of volatile chemicals.

There is uncertainty involved in assessing the sites, amount, frequency and duration of releases of new chemicals to the environment. Initial release and exposure assesments performed during the evaluation of new industrial chemicals under Section 5 of The Toxic Substances Control Act (TSCA) are based on calculations and estimates made before manufacturing of the chemicals is initiated. Monitoring data on releases of new chemicals are not routinely required of manufacturers and users and usually are not available. The expense of environmental monitoring and the lack of adequate detection methods contribute significantly to the absecnce of such data, also.

New industrial chemicals which are toxic may pose a risk to both terrestrial and aquatic life depending upon the time place, magnitude and duration of the exposure. Since releases to receiving streams are a standard practice in the manufacturing, processing and use of industrial chemicals, aquatic life appears to be exposed much more frequently than terrestrial life and over a larger geographical area. Data have not been collected and analyzed, however, to support and better characterize the temporal aspects and relative magnitude and frequency of terrestrial and aquatic exposures to industrial chemicals.

The response of aquatic and terrestrial populations to exposure by a toxic industrial chemical will vary depending on the toxicity of the chemical, the nature, magnitude and duration of the exposure and the physical and chemical conditons exisitng at the time. The response may be direct or indirect. The exposure may cause acute mortality in all or a portion of the population or community or it may cause reproductive impairment or sublethal,but adverse effects, to exposed organisms. Structural as well as functional units of the exposed ecosystems may be damaged or destroyed,and that damage may be transient or permanent.

NEW TOXIC CHEMICAL SOURCES, RELEASES AND EXPOSURES

Sources and Releases

TSCA provides information on sources of new industrial chemicals, their

416 new chemicals were reviewed by OTS. The annual production of approximately 3 percent of those chemicals was estimated to be greater than 5 million kilograms. Production volumes between a million and 5 million kilograms were calculated for 12 percent of the chemicals, 500,000 to one million killorgrams for 8 percent, 100,000 to 500,000 kilograms for 22 percent, and 1,000 kilograms or less for 19 percent of the chemicals reviewed.

Production volume information available for new chemicals at the time of the Section 5 review, such as that just cited, is based on intended, not actual, production figures and it may overestimate or underestimate significantly the real production volumes. The difference between the calculated and real production figures may in turn lead to significant errors in the OTS exposure assessments. Nevertheless,unless specifically notified to the contrary, manufacturers are not required to inform OTS of subsequent changes in production volumes when manufacturing commences.

Industrial chemicals may be released to the environment from manufacturing and processing facilities and use and disposal sites. Some uses and certain disposal practices may result in releases from non-point sources. Accidental releases from spills may also occur although spills are not considered currrently by OTS in its environmental exposure assessments. For the most part, however, it appears that most releases to the environment will originate from point source discharges.

Exposures

The quantity of an industrial chemical reaching the environment depends on a number of variables, including manufacturing and processing practices, treatment of the industrial discharge before release to a receiving stream and the effectiveness of that treatment, the properties and characteristics of the chemical and the volume of chemical being manufactured and processed. Some or all of these parameters may vary from one chemical to another.

A variety of other factors influence the nature of environmental exposures which result when an industrial chemical is released to the environment. Included among those factors are the temporal aspects of the release, the persistence of the chemical, the frequency of the releases and the properties of the chemical which affect its fate and movement once it enters the environment. The accuracy of the environmental exposure assessments for new industrial chemicals depends on the accuracy of the information available concerning the expected releases and the fate of the chemical in the environment.

Manufacturing and processing sites for any particular chemical usually are limited to a few locations, frequently no more than one or two. The site or sites at which a chemical is to be manufactured and processed are identified during the Section 5 review, and in some instances, the use sites are known as well. However, once the chemical passes the Section 5 review and is placed on the TSCA Inventory, it may then, unless otherwise restricted, be manufactured and processed by anyone at other sites throughout the country and in any quantity.

Many of the new industrial chemicals are intended for widespread use and, to the extent they are used widely, they may be released to the environment at a large number of sites. Many of the manufacturing, processing, use and disposal sites may also release to the environment a variety of other industrial chemicals, some of which may act in an additive manner with the new chemicals to increase the toxicity of one or both and thus increase the potential for environmental damage to occur. At the present time, the OTS exposure assessments do not consider the additivity of other industrial chemicals entering the environment from the same or other sites.

Since exposure information on industrial chemicals not yet in production is based on calculations and estimates which are subject to uncertainty and since monitoring data on most industrial chemicals are not being developed voluntarily by manufacturers and processers, exposure assessments for new industrial chemicals are, at best, subject to the same uncertainty. Moreover, no mechanism is in place currently to verify the accuracy of the conclusions of the Section 5 reviews regarding the potential for adverse ecological effects.

Quality and Completeness of Information

Premarket testing of new industrial chemicals is not a routine requirement in the U.S. Consequently, ecotoxicity data and exposure information available for use in a Section 5 review for ecological effects are extremely limited.

Ecotoxicity Data :

o Ecotoxicity data are available for less than 10 percent of the new chemicals reviewed by OTS since 1979.

o Ecotoxicity data adequate for a reasoned ecological risk assessment are available for less than 5 percent of the new industrial chemicals introduced into U.S. markets since 1979.

o Quantitative structure activity relationship (QSAR) models are available for estimating the minimum toxicity of approximately 30 to 40 percent of the chemicals reviewed under Section 5, excluding polymers. If the models are properly applied, the minimum toxicity estimates are suitable for screening evaluations but not for definitive ecological risk assessments.

o QSAR models are available for estimating bioconcentration factors for industrial chemicals. If the QSAR models are used properly, the estimates they provide are generally good predictors of bioconcentration. However the models cannot be applied to industrial chemicals which have high octanol/water partition coefficients. Industrial chemicals having high octanol/water coefficients frequently are of environmental concern because of possible chronic toxicity and bioconcentration.

Exposure Data:

o Little if any environmental fate test data are available for chemicals undergoing Section 5 reviews.

o Data bases and techniques are available for estimating many environmental fate parameters on the basis of chemical and physical properties. The accuarcy of these estimations, however, seldom are verified.

o Release estimates include a number of uncertainties resulting from the use of calculations in place of experimental data.

o Several models are available for assessing the potential exposure of ecological systems to industrial chemicals. The outputs of the models, however, are subject to the same uncertainties as the release estimates.

Risk Assessments of New Chemicals:

o Ecological risk assesments of new chemicals under Section 5 are based on the so-called "quotient method" which involves comparing the estimated environmental concentration to a concentration of the chemical estimated to cause a specific effect. The quotient method provides no information regarding important indirect effects of chemicals on ecological system. It also does not take into account other direct effect endpoints.

o Current ecological risk assessment methods do not provide a range of options for risk management.

STATUS OF CURRENT AND REASONABLY PROJECTED CONTROLS

Controls to safeguard the environment against the adverse effects of new industrial chemicals provided by Section 5 reviews are effective only in those instances where there is enough information to adequately assess the toxicity of the chemical and the nature of the releases to the environment.New chemicals which have passed through the Section 5 review and are placed on the TSCA Inventory without restrictions can then be manufactured, processed, used and disposed of in any quantity, at any location and by any manufacturer.

In 1986, for example, 118 chemicals suspected of being toxic to aquatic life were dropped from further Section 5 review because premanufacture production, processing and use information indicated that there would be no environmental releases or that releases which might occur would not result in environmental concentrations great enough to cause environmental damage. However, because exposure estimates developed during the Section 5 review were based on specific conditions such as production and processing methods, production volume, and use and disposal practices, any changes in those parameters could result in releases which would be damaging to the environment.

Since new industrial chemicals which go on the TSCA Inventory without restrictions are not routinely tracked, there is no opportunity to prevent environmental damage resulting from changes in the exposure parameters.

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PROBLEM #28 : NEW TOXIC CHEMICALS

INFORMATION SOURCES

- Monthly PMN and TMEA Statistical Summary-Report for September 1986. Premanufacture Notice Management Branch, Chemical Control Division.
- CBI PMN Statistics Report for 3rd Quarter of FY 85.
- Analysis of Withdrawn and Voluntarily Tested PMNs. Centaur Associates, Inc. 1985.
- Analysis of TDIS Data on PMNs by Use, Chemical Function and Production Volume. Centaur Associates, Inc. 1983.
- Chemical Control in the United States. Accomplishments Under the Premanufacture Notice Management Program. Office of Toxic Substances. 1987.

EVALUATION OF PROBLEM : NEW TOXIC CHEMICALS.

STRESS AGENT	SCALE OF EFFECT			FRESHWATER ECOSYSTEMS			
(SOURCE)	BIO-SPHERE	REGION-AL	ECO-SYSTEM	BUFF. LAKES	UNBUF. LAKES	BUFF. STREAM	UNBUFF. STREAM
AIR	?	?	?	?	?	?	?
WATER	L	M	H	H	H	H	H
TERRESTRIAL	L	L	?	C	C	C	C
OTHER	?	?	?	?	?	?	?

				MARINE & ESTUARINE ECOSYSTEMS		
				COASTAL	OPEN OCEAN	ESTUARIES
AIR	?	?	?	?	-	?
WATER	L	M	H	M	-	H
TERRESTRIAL	L	M	H	M	-	H
OTHER	?	?	?	?	-	?

				TERRESTRIAL ECOSYSTEMS				
				CONIF.	DECID.	GRASS'LDS.	DES./S.A.	AL'P/T
AIR	L	L	L	-	-	-	-	-
WATER	L	L	L	-	-	-	-	-
TERRESTRIAL	?	?	?	?	?	?	?	?
OTHER	-	-	-	-	-	-	-	-

				WETLAND ECOSYSTEMS				
				FRESHWATER				SALT-
				ISO'L./UNBUF.		ISO'L./BUF.	FLOWING	WATER
AIR	?	?	?	?	?	?	?	?
WATER	-	H	H	H	H	H	H	H
TERRESTRIAL	-	?	M	?	?	?	?	?
OTHER	-	-	-	-	-	-	-	-

Ecological Risk from Biotechnology # 29

Introduction

Included under the topic "biotechnology," as related to OPTS issues, are microbial pesticides and genetically engineered organisms. Microbial pesticides include bacteria, blue-green algae, fungi, viruses and protozoa. Genetically engineered organisms include organisms that are genetically modified to contain genetic material from dissimilar source organisms.

EPA has chosen to focus, both under FIFRA and TSCA, on microorganisms that are used in the environment, are pathogens, or contain new combinations of traits (e.g. contain genetic material from dissimilar sources or are nonindigenous to areas where release and use is intended). EPA believes these categories have sufficiently high potential for widespread exposure and adverse effects or great uncertainty concerning potential effects as to merit close regulation under OPTS statutes. Identifying these subsets of biotechnological products is an attempt by EPA to separate products on the basis of potential risk.

Uniqueness of Risk from Biotechnology Products

Traditionally, ecological risk assessment for most pesticides and many toxic substances focuses on geographically defined areas of use, exposed habitats and the potential for adverse effects to organisms in the area.

Typically, crop sites and use areas have been used to identify the application and exposure areas. Off-site transport is assumed to occur via aerial drift, run-off, leaching and bioaccumulation. In a few cases aerial drift has been obserrved to transport residues many miles off-site. In the majority of cases however, ecological effects have been considered more or less restricted to defined areas of impact.

Pesticides and toxic substances derriving from biotechnology pose a different sort of ecological hazard. This is primarily due to their effects on organisms of specific taxonomy, regardless of geographic location. For example, the risk from a given engineered pathogen may be to all lepidopterans irrespective of range because the pathogen is host-specific, capable of wide distribution and not restricted to a specific eccosystem, life zone, crop site or habitat. As such, risk must focus on organisms, entire species, families, and higher taxonomic groupings. Risk assessment predicated on these effects is a new undertaking by OPTS, and is largely untried todate. Ecological effects due to biotechnologically derrived products are unpredicable and potentially of global impact.

Traditional concepts of assessing hazard by ecosystem may not be the most useful framework for assessing risks from these new products New approaches should be sought and risk assessment should be tailored to fit the new kinds of risks posed by biotechnology.

Nature of Risk from Biotechnology Products

Latency of Adverse Effects

Certain bacteria, fungi, protozoa and viruses can require a long incubation or latent period before pathogenic effects are observed. Acute, short-term toxicity tests might not be sufficient to detect these effects.

Environmental Releases

Although many microorganisms will be biologically contained by inherent limitations on their growth and survival, some may reproduce and increase in numbers in the environment beyond the amounts originally released. Some will also have independent mobility, or may spread beyond the area in which they are intended for use.

Nonindigenous Microorganisms

It is difficult to predict whether a nonindigenous microorganism will be subject to the physical and biological controls present in the environment where it is to be introduced. Examples of nonindigenous microorganisms (pathogens) that have caused significant adverse effects are chestnut blight fungus and Dutch elm disease fungus.

Microorganisms with New Traits

Microorganisms with new trailts of characteristics may behave in unpredicatable ways. Traits may be new to the organism (as a result of genetic engineering) or traits may be new to the environment (as a result of introduction of nonindigenous organisms). In either case potential effects are highly unpredicable at present.

Some new traits may affect the microorganism's characteristics of, for example, survivability, host range, substrate utilization, competition with other organisms, or protein or polysaccharide production. Potentially even relatively small changes in characteristcs such as these may result in fundamental changes in community composition, structure or function.

Risks to Nontarget Genetic Material

The function and behavior patterns of recombined genes is poorly understood and unpredictable in some cases. There exists the potential for genetic transfer to unintended recepients. The environmental fate of genetically engineered organisms is not clearly known, nor are the potential effects from competition with native organisms.

Evaluation of Risk

Risk may range from zero, as when a microorganism pathogen is short-lived and effective only against the target, to risks of global eradication of an entire taxonomic group should a genetically engineered organism escape it's intended use area and function and be carried by specific hosts to all taxonomic group members.

Thus far, reviews of small-scale field testing proposals for genetically engineered microbial pesticides have emphasized some questions that have not been as significant in the assessments of naturally occuring microbial pesticides. For example, OPP has identified potential risks associated with the transfer of inserted genetic material to other organisms, the competitiveness of the engineered organism compared to the parental organisms in the environment, and the ability of the engineered organism to become established in a new ecological niche and thereby pose a potential adverse impact to the environment.

Risk evaluation for biotechnological products is in it's first stages and is inherently filled with uncertainty and the need to develop new frameworks for evaluation. Old criteria may not be applicable and new concepts for assessing risks to entire taxonomic groups need to be developed. Much basic research in risk assessment and risk management is needed in this area.

Bibliography

Federal Register, Thursday, June 26, 1986: 23321-23324

Ghassemi, M. *et al*. 1983. Environmental International. (9): 39-49.

Ecological Risk Workgroup

Problem #30: Plastic in the Marine Environment

Overview

Plastic has become a dominant ingredient in the composition of modern household goods, furnishings, packing materials, tools, equipment and machinery. Although plastic was invented only a little more than 40 years ago, its presence, either as a raw material or a manufactures product, is worldwide. Unfortunately the features of plastic which make it so convenient and useful also assure its persistence when released, lost or abandoned in the environment.

Sources

While plastic material may orginate both on land and at sea, most of the plastic debris entering the marine environment is believed to come from ocean sources such as shipping and commercial fishing. Deliberate disposal at sea of plastic items appears to be one of the major sources of plastics entering the marine environment. Another important source is commercial fishing which introduces both domestic waste as well as plastic fishing gear to the marine environment. Oil rigs and drilling platforms are a third major source from which plastic debris enter the ocean.

Land-based sources discharging plastics to marine environments include industrial sites where plastics are synthesized from petrochemicals or where plastic products are manufactured. In metropolitan areas, primarily along the North Atlantic coast, sewer systems combined with storm water runoff systems contribute large amounts of plastic debris via outfalls in marine areas. Municipal sewage sludge dumped in the ocean is also a potential source of plastic debris.

The types of plastic debris found in the marine environment includes both manufactured and raw plastic articles. Manufactured articles are those which have been fabricated into consumer products such as fishing gear, packing and packaging materials, six-pack connectors, plastic sheeting bags, and bottles. Raw plastics usually are in the form of small spherules or beads, synthesized from petrochemicals and used to manufacture

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plastic products. Both manufactured and raw plastics enter the marine environment by one or more routes - deliberate and accidental discharge or dumping at specific sites, indiscriminate but deliberate discharge or dumping in shipping canes, accidental loss or deliberate abandonment of plastic material at sea.

Impact Responses

A growing body of evidence indicates that plastic items discharged, lost or abandoned are adversely affecting the oceans and marine life in a variety of ways.

The presence of plastics in the environment is a hazard to marine life because of the potential for (1) entanglement or entrapment and (2) ingestion of plastic materials which may be toxic or cause physical blockage of the digestive system. Among marine life which has suffered adverse effects from plastic debris are several endangered and threatened species of marine mammals, sea turtles, sea birds and marine fish. Certain economic losses also are associated with the presence of plastics in the oceans including losses in commercial fisheries due to "ghost fishing" or entrapment of fish by discarded commercial fishing gear, cost of beach cleanup to remove plastic debris, and aesthetic degradation of beach areas.

Detailed Description of Sources, Releases and Exposures.

Sources:

Substances and quantities released -

The types of plastics found in the marine environment include a broad range of objects. Certain items can be traced to a particular source while others may originate from several different, and sometimes unidentifiable, sources. Whatever the case, it is believed that most plastic debris in the marine environment comes from ocean sources. Prominent among plastic debris found in the marine environment are the following:

(1) Fishing year

(a) nets - Most commercial fishing nets in use today are composed of synthetic fibers (vinylon, vinylidine, vinyl chloride, polyethylene, polyester, polypropylenel) or combinations of plastic fibers. Pieces of net released as a result of damage to an intact net or discarded during repair of damaged nets, or whole nets lost accidentally or deliberately discarded at sea are found in the marine environment. Accurate figures on the quantity of such debris, however, are not available currently. There are, however, figures on the quantity of plastic netting in use in some of the major commercial ocean fisheries which provides an insight of the potential magnitude of the problem.

The total length of all gill nets available to the 15 major North Pacific gill net fisheries is 170, 466 km - if strung end to end, this is enough net to extend about four times the length of the equator. Commercial fisherman from Japan, Taiwan and Korea, set out approximately 1,065,510 miles of drift net each year. Japanese vessels fishing for salmon in U.S. territorial waters set out 2,580 kilometers of gill net each day.

Trawl nets, bag-shaped nets towed behind a vessel, are believed to the second most commonly lost type of net. Approximately 5,500 km of trawl net are used by the 12 major foreign and domestic trawl fisheries in the North Pacific. Desired observations of trawl net losses in 1984 revealed the following: 322 commercial fishing vessels operating off Alaska lost 65 nets or portions of nets in one year.

Although there are no reliable estimates of the total quantity of gill or trawl net lost or damaged, some relevant observation has been recorded. A research vessel found 3,000 m. of lost gill net in the western North Pacific. In a 100 acre plot of a major gill net fishing ground off the New England Coast, 10 lost gill net were found. Official records maintained under the Fishermen's Vessel and Gear Damage Compensation Fund list 525 gill nets, 50 feet or more in length, (30 miles) lost in 1985 and 320 (18.2 miles) in 1986. These records include only nets lost in Federal waters.

(b) Traps - plastic netting is used in the construction of lobster, crab, and eel traps. In 1984. 2.5 million traps were used in the New England lobster fishery; approximately 20% of those were lost. Some 30,000 King crab trap have been lost in Alaskan waters since 1960. Along the West coast of Florida in 1984, over 25% of the 96,000 stone crab traps in use were lost.

(c) Plastic buoys and ropes - Plastic rope and buoys are put to a variety of uses by commercial and sports fisherman and in various types of water recreation. There have been few attempts to quantify the amount of rope or the number of buoys lost. Files kept by the Fisherman's Vessel and Gear Damage Compensation Fund suggests that large numbers of buoys and great quantities of plastic rope are lost at sea. In the states of Washington and Oregon a total of 1042 buoys and 465,906 feel of rope were reported lost in 1985 alone. Crabbers use two to three buoys per King crab trap; 30,00 King crab traps and at least twice that many buoys have been lost in Alaska since 1960. Since 16,611 stone crab traps lost in the Gulf of Mexico represents a loss of 16,611 buoys and 157 miles of nylon rope.

d. Monofilament fishing line - large quantities of monofilament fishing line are lost or discarded overboard each year. There are, however, no records to quantitate the magnitude of the problem.

e. Cargo Associated Wastes - Two items of debris orginating from cargo shipping activities which are known to affect the marine environment are plastic strapping bands and large pieces of plastic sheeting. Strapping materials are used extensively to bind corrugated cartons containing fish, fishing nets beverage containers and various other packing cartons. While there is no information on the total length of strapping material produced annually, it is believed to be considerable based on estimates of the total amount sold in the U.S. (approximately 125 million pounds).

Large sheets of plastic are used in cargo shipments to cover items during transport and frequently are discarded. One pound of this plastic sheeting will cover 28 square feet of beach area. Documentation is not available on the amount of plastic sheet debris which is generated, although plastic sheeting has been reported as the most abundant litter items found on at least one seashore area examined.

f. Domestic Plastics - Plastic items used for domestic purposes makes up a diverse category of plastic found in the marine environment. Included in this category are large, sheets, six-pack connectors, containers, bottles, tampon applicators and pieces of styrofoam.

The presence of small plastic particles in the marine environment has been documented numerous times. Included in this category are raw plastic pellets and fragments or remanants of manufactured plastic items. Both raw plastic pellets and plastic fragments have been found in high concentrations (raw plastic pellets - 34,000/Km^2; and plastic fragments - 305/Kilometer of beach).

Location, size and number of sources

While the plastic debris found in the marine environment may take in a broad array of items which may originate from land or sea, it is believed that most of it comes from ocean sources. The disposal of wastes by ocean sources is common because it is "inexpensive" and convenient. The disposal of wastes from ocean sources is believed to exceed 7 million meteric tons a year. Commercial fishing operations are a source of plastic debris in the form of domestic wastes and fishing gear. There are, worldwide, 120,00 commercial fishing vessels over five tons. These ships generate about 340,00 metric tons of domestic wastes, some part of which is plastic debris. In addition, the world's commercial fishing fleet generates annually a thousand metric tons of plastic fishing debris including nets, lines, buoys.

The world's merchant shipping fleet which consists of 71,00 ships (in 1979) disposes of approximately 11,00 metric tons of plastic debris via domestic wastes each year, and an unknown quantity of plastic debris among the 5.6 million metric tons of cargo-waste. These merchant ships also are a source of raw plastic pellets which are "lost" during loading or unloading or which are used as packing. Large passenger vessels produce some 504 metric tons of plastic debris each year while the one million recreational boats in the U.S., in marine waters, are the source of 340 metric tons of plastic debris.

There are approximately 175 off shore drilling rigs in U.S. waters and these are the source of an undertermined amoumt of plastic debris which enters the marine environment. The waste plastic from these sources includes plastic sheeting, marking buoys, plastic drums, computer write protection rings, drilling pipe thread protectors, plastic ropes and filters.

Land-based sources of plastic wastes contributing to the marine problem include industries which synthesize plastic and manufacture plastic articles, wastewater treatment plants and storm water runoff systems with outfalls in marine areas. Data on the number of these sources and their locations have not been assembled.

Current Controls

Legal authority exists pertaining to ocean dumping and disposal of hazardous wastes, and regulating the taking of marine mammals and fish. Much of it may be applicable to controlling the kind of plastic debris that results in entanglement of marine organisms, but none of it addresses the issue specifically. Included in the existing authority are laws that govern ocean dumping, including dumping of plastics; pollution laws that govern disposal of hazardous wastes and regulate water quality; fish and wildlife conservation laws that regulate how fish and marine animals may be taken by humans.

Relevant international authorities include the London Dumping Convention, the MARPOL Protocol, the U.N. Regional Seas Program, the United Nations Law of the Sea, and other agreements similar in pattern to these major conventions. Each of these authorities is aimed at controlling dumping in the oceans. Certain substances are prohibited expressly, and others are permitted to be dumped under a regulatory scheme adopted by each of the nations party to the agreements. The major concern in relating these agreements to the entanglement issue is whether or not dumping of plastics is covered under the prohibitions. The key issue in using the London Dumping Convention to control dumping of nets is whether or not a net is discarded purposefully, or incidentally in the course of normal fishing operations. The MARPOL Protocol, on the other hand, does expressly denote fishing nets among prohibited disposals, and additionally covers accidental disposals. However, Annex V, which contains the language relevant to plastics, must be ratified by at least 15 nations whose fleets jointly constitute 50 percent of the gross tonnage of the world's shipping. To date, 14 nations have ratified the Annex, but their combined tonnage falls short of the requirement. The U.S. has not ratified the Optional Annex V. A major concern with all these agreements is that enforcement is difficult and left to the discretion of each signatory nation.

U.S. domestic legislation governing ocean or inland dumping is typified by the Rivers and Harbors Act of 1899, the Act to Prevent Pollution from Ships, the Marine Protection, Research and Sanctuaries Act (MPRSA), and the Clean Water Act. In addition to these major authories, there are several other laws which may be applicable in narrow circumstances. Pertinent considerations in determing whether these laws are applicable to entanglement include the extent of their jurisdication, and whether or not plastics are covered substances under the definitions of each law. The major aurthority is the MPRSA or "Ocean Dumping Act." However, its applicability may be limited in that it regulates transportation for the purpose of dumping, rather than dumping itself. The second type of authority, aimed at land-based disposals, can be found in the Resource Conservation and Recovery Act, which regulates disposal of solid waste and prohibits dumping of hazardous waste. The key question with regard to plastics and entanglements is whether netting and other plastic debris can be defined as "hazardous" under the law. The final group of U.S. authorities examined is wildlife conservation law. Under these laws, such as the Marine Mammal Protection Act, the Endangered Species Act, the Migratory Bird Treaty Act, and the Fishery Conservation and Management Act, it is the taking of marine mammals and birds that is prohibited, rather than the disposal of materials that lead to entanglement. Under each of these authorities, entanglement would constitute a violation as an illegal "taking." As with other legislation, enforcement is difficult, since the prohibited activity takes place at sea.

Each of the states has enacted legislation on the state level to implement federal pollution control laws such as the Clean Water Act and the Resource Conservation and Recovery Act. The provisions of these laws are substantially the same as the federal law, though may be more restrictive. In addition, a series of laws known as "bottle bills" can be viewed as a solution to one segment of the entanglement problem. These laws in may states prohibit the sale and distribution of beverage containers that are connected by plastic rings or similar devices unless the connectors are bio- or photodegradable.

There are very few existing programs that address, or have the potential to address, the problems of plastic marine debris, even in areas where the problems are significant. The only federal agency that has a program specifically relating to entanglement is the National Marine Fisheries Service. Some existing federal programs, such as the National Sea Grant College Program, and the Chesapeake Bay program which resulted from a 5-year EPA study, are potentially relevant to the problem of plastic marine debris. Some states have programs that relate directly to legislation, for example beach cleanup programs and recycling programs. A limited number of private entities, including corporate and non-profit organizations, have specific programs relating to entanlgment or other aspects of marine debris.

Availability and Quality of Information

Evidence is emerging that the disposal of plastic debris in the marine environment is a serious problem for a number of species and for communities and user groups that depend on the marine environment. Even when the information is anecdotal, as it is in many cases, a synthesis of such anecdotal reports suggests that the biological and economic impacts may be significant.

The major sources of plastic debris in the marine environment have been identified. Unfortunately, there have been few directed studies concentrating on particular regions or particular populations of animals.

Management agencies, at the federal, state and local levels, are not yet fully aware of the magnitude of this issue, and have not directed their efforts toward investigating the biological and economic impacts associated with marine plastic debris and consequentially relatively little data has been compiled or evaluated.

Problem #30

Evaluation of Problem

Ecosystems		Intensity of Biological Effects.(1)	Reversibility of Impact	Exposure(2)	Total Ecological Risk
Freshwater	Buffered Lakes	?	?	?	?
	Unbuffered Lakes	?	?	?	?
	Buffered Streams	?	?	?	?
	Unbuffered Streams	?	?	?	?
Marine and Estuarine	Coastal	?/M	?	?/M	?
	Open Ocean	?/M	?	?/M	?
	Estuaries	?/M	?	?/M	?
Terrestrial	Coniferous Forest	?/<	?	?	?
	Deciduous Forest	?/<	?	?	?
	Grassland	?/<	?	?	?
	Desert/Semi-Arid	?/<	?	?	?
	Alpine/Tundra	?/<	?	?	?
Wetland	Freshwater-isolated	?	?	?	?
	Freshwater-flowing	?	?	?	?
	Saltwater	?/	?	?	?

(1) Significance of ecological effects of plastic debris discarded, lost or abandoned.

(2) Documented presence of considerable quantities of plastic debris.

(?) (? = uncertain because of insufficient knowledge.)

Reference

Center For Environmental Education - 1986. Use and Disposal of Nondegradable Plastics in the Marine and Great Lakes Environments. (Draft - July 1, 1986).

(Major review of literature on plastics in the environment with an extensive list of references.)